G.T.A.R.A. *(Grip/Grasp Training with Active Range of Motion Activities Using Guitar)*: A Randomized Controlled Trial Using Guitar Lessons for Restoring Hand Function among Patients with Unilateral Hand Impairment

Kreza Geovien G. Ligaya, MD,[1] Sharon D. Ignacio, MD,[1] Daniel Joseph S. Morabe,[2] Nathan Neil V. Manimtim, PhD[2] and Manuel Peter Paul C. Jorge II, MD[3]

[1]*Department of Rehabilitation Medicine, College of Medicine and Philippine General Hospital, University of the Philippines Manila*
[2]*Department of Strings and Chamber Music, College of Music, University of the Philippines Diliman*
[3]*Department of Physiology, College of Medicine, University of the Philippines Manila*

ABSTRACT

Objective. To determine the effects of guitar lessons (intervention group) in comparison to conventional occupational therapy (OT) sessions (control group) on hand function of chronic stroke patients with unilateral hand impairment.

Methods. This randomized controlled trial enrolled 34 chronic stroke patients with unilateral hand impairment. Participants were grouped randomly into intervention (guitar lessons) and control (conventional occupational therapy) groups. Each group participant underwent a total of eight consecutive therapy sessions, twice weekly for an hour each session, at the designated treatment rooms in the Department of Rehabilitation Medicine of the Philippine General Hospital. Pre- and post-treatment evaluations were done to assess range of motion, grip and pinch strength, and hand functions. Satisfaction surveys were answered at the end of the 8-therapy session.

Results. Improvements in hand function were assessed through measurement of range of motion (ROM), grip and pinch strength, and with the use of Beery-Buktenica Developmental Test of Visual-Motor Integration, Jebsen-Taylor Hand Function test, and Purdue Pegboard Test of Manual Dexterity. In this study, the comparison of actual change of passive range of motion (ROM) of the impaired hand from pre- to post-treatment between control and intervention groups showed no statistically significant difference. No statistically significant difference between groups were also observed for the active ROM of the impaired hand. Comparison of function of the impaired hand pre- and post-treatment between control and intervention groups showed no statistically significant difference except for an observed greater improvement with the control group in motor coordination (median [IQR] 0 [-1 to 0] vs 1 [1 to 5], p = 0.004), tip (median [IQR] 0.33 [0 to 0.75] vs 1 [0.58 to 1.5], p = 0.006), and 3-jaw (median [IQR] 0.5 [0 to 0.92] vs 1.08 [0.41 to 2], p = 0.043) pinch strength.

In evaluating the satisfaction of participants in both groups, higher mean scores were observed in the control group. No statistically significant difference in most of the questions in the satisfaction survey in both groups.

All participants in both groups displayed 100% compliance in attending onsite treatments. Despite not showing statistically significant difference between groups (p = 0.721), an 11.8% tendency for better compliance is found in the intervention group.

eISSN 2094-9278 (Online)
Published: November 15, 2024
https://doi.org/10.47895/amp.v58i20.9334

Corresponding author: Kreza Geovien G. Ligaya, MD
Department of Rehabilitation Medicine
Philippine General Hospital
University of the Philippines Manila
Taft Avenue, Ermita, Manila 1000, Philippines
Email: ligayakreza@gmail.com
ORCiD: https://orcid.org/0009-0009-0874-6775

Conclusion. The specific guitar lesson created and performed in this study as used by 17 participants of the intervention group have brought about improvement in hand function that is comparable with those who underwent traditional occupational therapy. This may be most helpful in areas with limited access to rehabilitation facilities and occupational therapy services. This may also be used as a continuing activity of chronic stroke patients at home to help improve hand function.

Keywords: music therapy, guitar, stroke rehabilitation, occupational therapy

INTRODUCTION

Hand function, which is the capacity of the hand to manipulate objects in coordination with the bones, muscles, and joints of the rest of the segment of the upper extremity, is one of the more common impairments sustained by stroke patients.[1-3] It has a negative impact on individuals since hand function helps an individual accomplish daily ordinary tasks as well as specialized duties when employed. For hand function to return, sustained and regular physical and occupational therapies are needed for a period of time (e.g., months to years). However, limited rehabilitation facilities, long waiting time for treatment to commence, high financial and opportunity costs of services, and reduced patient interest in treatment programs affect low completion rates of treatment. According to the two recent studies conducted by Collantes et al., "there are only 452 rehabilitation centers serving 148 stroke cases per 100,000 population in the country," and most of which are in highly urbanized areas.[4,5] The high cost of post-stroke rehabilitation care and the limited therapy coverage from health insurance further hampers access to and continuation of rehabilitation.[5]

Use of music in treatment has been advocated for many years. Past research shows that therapeutic instrument music performance (TIMP) for fine motor exercises provides both pleasure from the music produced and motivation for individuals to participate in rehabilitation.[6] A study by Lim et al. compares TIMP with Traditional Occupational Therapy (TOT) on endurance, self-perceived fatigue, and self-perceived exertion of 35 hospitalized patients all with neurological disorders and recently underwent orthopedic surgery in physical rehabilitation. The study explored the effect of active musical experience in TIMP with musical cueing (such as rhythmic auditory cueing) on participants' perception of fatigue and exertion. The results showed that there is no significant difference between the endurance of the TIMP and TOT groups, but found statistically significant differences when comparing their perceived fatigue and exertion. TIMP showed significantly less perception of fatigue and exertion levels than TOT, and the study concludes that TIMP may be used as an effective sensory-motor rehabilitation technique to decrease the perceived fatigue and exertion among patients in physical rehabilitation.[7] In a case report done in 2018 done by Ligaya et al. wherein a set of guitar exercises where provided to a young chronic stroke patient, it showed improvement in hand function and coordination as evidenced by the timed alphabet writing test, Jebsen-Taylor Hand Function test, and Purdue Pegboard test.[8] Though there was no improvement in speed, there was improvement in handwriting and grasp patterns which could not be measured with the tools used in the case report.

At present, there are still no studies in the Philippines on the active use of guitar by individuals with hand impairment (chronic stroke) as a tool for improving hand motor function.

All this data led the proponents to consider the classical guitar as a possible tool for the rehabilitation of a patient with unilateral hand impairment. Almost all the necessary movements used in current occupational therapy (OT) are already part of standard classical guitar technique. Compared to other instruments such as the keyboard, which predominantly uses flexion movement for playing, the guitar technique has a wider variation of movements closer to the different functions of the standard therapeutic devices. The relatively lower cost, ease of transport, and wider availability of the well-loved guitar in both urban and rural areas of the Philippines make its use quite feasible.

OBJECTIVES

General Objective

To determine the effects of guitar lessons (intervention group) and conventional occupational therapy sessions (control group) on hand function of chronic stroke patients with unilateral hand impairment.

Specific Objectives

1. To describe the demographics of participants in the study (e.g., age, sex, handedness pre-CVD, affected hand post-CVD, type of CVD, hobbies, pre- and post-CVD employment, pre-employment activities, length of time participant has had the hand impairment)
2. To compare the pre- and post-treatment hand function of those in the control group (conventional occupational therapy) and intervention group (guitar lessons), in terms of: Physical evaluation (range of motion, tone, muscle strength), Objective tools (Beery-Buktenica Developmental Test of Visual-Motor Integration, Jebsen-Taylor Hand Function test, Purdue Pegboard test of Manual Dexterity, and Hand grip and pinch strength test)
3. To compare the level of satisfaction of participants between treatment groups (control group versus interventional group), and
4. To determine the level of compliance between treatment groups (control group versus intervention group).

METHODS

Study Design

This is an open-label, single-center, non-inferiority randomized controlled trial.

Research Registration

The study proposal was registered with the University of the Philippines Manila last September 6, 2021 with Reference Number RGAO-2021-0930.

Ethics Approval

The study protocol and all its related documents were approved by the University of the Philippines Manila Research Ethics Board (UPMREB) Review Panel 2 last December 23, 2021 with code number UPMREB 2021-0573-01.

Participant Selection

Inclusion criteria

1. Participants must be 19 to 65 years old who sustained unilateral hand impairment (left or right upper extremity) secondary to stroke (cerebrovascular disease), either infarct or hemorrhagic, for the past six months (at the least).
2. The participant must be a patient of the Department of Rehabilitation Medicine of the Philippine General Hospital (DRM-PGH).
3. The participant must have controlled hypertension and other comorbidities (such as diabetes, cardiac disease).
4. The participant must be fully vaccinated against COVID-19.
5. The participant must be willing to visit DRM-PGH for evaluation and treatment.
6. The participant may have had formal hand therapy sessions through physical therapy or occupational therapy.
7. Assessed muscle tone using the modified Ashworth scale of the affected upper extremity may be spastic with a grade of 1 (slight increase in muscle tone described as catch and release or minimal resistance at end range), 1+ (slight increase in muscle tone described as catch then with minimal resistance throughout the remaining range of motion), or 2 (marked increase in muscle tone in most of the range of motion with minimal difficulty moving towards flexion).
8. The distal aspect (wrist and hand) of the affected limb of the patient must be at least 3/5 (muscle passing over the joint being evaluated could move it to full range of motion against gravity with no resistance) on manual muscle test strength.
9. The patient must have good sitting balance and tolerance, intact cognitive function that will enable him or her to focus on the exercise for an hour per session.
10. Patient's vision must enable him or her to see and follow instructional material with minimal difficulty.
11. Patient must not have significant limb contractures that will affect performance and participation in the study.

Exclusion criteria

1. Participant with uncontrolled comorbidities that make them more vulnerable to recurrent stroke or COVID-19.
2. Participant with poor cognitive functioning (unable to follow instructions), aphasia (difficulty in expressive and/or receptive language), behavioral problems (unable to focus), poor visual acuity, or poor auditory capacity.
3. Participant with impaired sensation (inefficient tactile functioning or 50% sensory deficit of the hands), sensory-perceptual (poor hand-visual function), and proprioception of the upper extremity.
4. Participant with incoordination and hand tremors.
5. Patients with open or fresh wound of the affected limb, pressure sore of the sacrum or other parts of the body that will produce difficulty in positioning the patient with the guitar.
6. Patients with soft tissue contractures that significantly affect range of motion of fingers (ROM less than 50% of functional range).

Study Site

The treatment room for this study was in one of the rooms at the Gazebo garden of the Department of Rehabilitation Medicine of the Philippine General Hospital.

Sample Size

Using G*Power 3.1.9.2, a minimum of 34 patients or 17 each group were required for this study based on desired large effect size between intervention and control group in terms of hand function evaluation or level of satisfaction of the patient. This computation also accounted for 5% level of significance and 80% power.

Study Procedure

Thirty-four chronic stroke patients were recruited to participate in the study, each of them randomly grouped into control and intervention groups using systematic random sampling (non-blind). Chronic stroke is defined as stroke lasting more than 6 months from its onset.[9] Once a participant consented (signed informed consent form), participant interview (demographics), physical examination (muscle tone, range of motion of joints, pinch and grip strength, and hand function of the paretic extremity) and pre-treatment evaluation (pinch and grip dynamometer, Jebsen-Taylor Hand Function Test, Purdue Pegboard Test, Beery-Buktenica Developmental Test of Visual-Motor Integration) were done.

In both control and intervention groups, each participant was provided with course packs. Each participant of both groups underwent one pre-treatment assessment, eight therapy sessions done twice weekly, and one post-treatment assessment. At the end of each session, detailed home exercises were also given.

For the control group, standard of care occupational therapy was employed. A set of hand exercises were performed by each participant as guided by the occupational therapist at their own pace and capacity. Per treatment session lasted for 45 to 60 minutes only, with each exercise repeated 10 times per set for one set only. Each session was video recorded. The set of hand exercises included activities for finger flexion and extension (interphalangeal or IP joints and metacarpophalangeal or MCP joints of each digit), wrist flexion and extension, wrist ulnar (UD) and radial deviation (RD), forearm pronation and supination, and grip exercises using TheraPutty, grip dynamometer, power webs, and hand exercises for gross and fine motor skills (specific OT board).

For the intervention group, each participant was trained one-on-one by the guitar instructors (Co-Is) of the College of Music of the University of the Philippines Diliman to perform music pieces as guitar lessons. These guitar lessons included crucial hand and wrist movements such as finger flexion and extension, wrist flexion and extension, wrist ulnar and radial deviation, forearm pronation and supination, and grip. Performance of these lessons were done at the participant's own pace and capacity that lasted for 45 to 60 minutes only. Each session was video recorded.

At the end of eight therapy sessions, participants' experiences of the received treatment sessions were surveyed using a multiple-choice questionnaire translated to the Filipino language. Attendance diaries were provided to each participant at the beginning of the treatment session. These diaries were collected from each participant at the end of the last session. All measurements and data gathered were tabulated for analysis.

Statistical Analysis

Descriptive statistics were used to summarize the demographic and clinical characteristics of the patients. Frequency and proportion were used for categorical variables, median and inter quartile range for non-normally distributed continuous variables, and mean and SD for normally distributed continuous variables. Independent Sample T-test, Mann-Whitney U test and Fisher's Exact/Chi-square test were used to determine the difference of mean, rank and frequency, respectively, between Control and Intervention group. Paired Sample T-test, Wilcoxon Sign Rank Test and McNemar Test were used to determine the difference of mean, rank, and frequency, respectively, on patients from pre- to post-treatment. All statistical tests were two-tailed tests. Shapiro-Wilk was used to test the normality of the continuous variables. Missing values will neither be replaced nor estimated. Null hypotheses were rejected at 0.05α-level of significance. STATA 13.1 was used for data analysis.

RESULTS

Participant profiles were shown in Table 1. Most of the participants were 51 to 65 years old (58.8%), male (67.7%), right-handed prior to stroke (91.2%). Most of them have had an ischemic stroke (70.6 %) which is the blockage of the blood vessel to the brain, with an average of three years of stroke, and were with right hand impairment (55.9%) post-stroke. Concerning comorbidities, 73.5% have hypertension, 23.53% have diabetes mellitus, 14.7% have heart disease, and 26.5% have other comorbidities such as kidney disease and prostate enlargement. Many of them finished vocational courses (50%), were manual laborers (67.7%) pre-stroke, and unemployed (85.3%) post-stroke. Only 32.4% of them have had a history of playing the guitar. With all these variables, the data have shown no significant statistical difference in both control and intervention groups (except for other comorbidities). Hence, based on the results in Table 1, these variables maintained homogeneity of data in the study.

Looking into *other comorbidities* (p=0.017), a statistically significant difference was noted as there were eight participants from the control group who have comorbidities other than hypertension, diabetes mellitus or heart disease as compared to only one participant in the intervention group. Though it may have such a p-value, it is not clinically significant for this study in terms of effect in hand function evaluation.

Participants in the control group underwent traditional occupational therapy. According to Table 1, participants were mostly 51 to 65 years old (70.6%), male (58.8%), formerly right-handed (94.1%). Most of them have had an ischemic stroke (70.6 %), with an average of 3.67 years post-stroke, with right hand impairment (52.9%) post-stroke. Concerning their comorbidities, 88.2% have hypertension, 23.5% have diabetes mellitus, and 5.9% have heart disease. Many of them finished vocational courses (64.7%), were manual laborers (76.5%) pre-stroke, and unemployed (82.4%) post-stroke. Only 35.3% of them have had a history of playing the guitar.

Participants in the intervention group underwent guitar lessons. Most of them were 51 to 65 years old (47.1%), males (76.5%), formerly right-handed (88.2%). Most of them have had an ischemic stroke (70.6 %), with an average of 1.83 years post-stroke, with right hand impairment (58.8%) post-stroke. Concerning their comorbidities, 58.8% have hypertension, 23.5% have diabetes mellitus, and 23.5% have heart disease. Many of them reached tertiary level of education (47.1%), were manual laborers (58.8%) pre-stroke, and unemployed (88.2%) post-stroke. Only 29.4% of them have had a history of playing the guitar.

During the conduct of the study, all participants in both control and intervention groups displayed 100% compliance in attending onsite treatments. However, more were noted to be compliant in performing home exercises in the intervention group (n=12, 70.6%) than in the control group (n=10, 58.8%).

Analysis of the measured active ROM between control and intervention groups pre- and post-treatment are shown tabulated in Appendix A. The pre-treatment data for both groups showed a significant difference in active range of motion values compared to the control group in terms of

Table 1. Demographic and Clinical Profile of Chronic Stroke Patients

	Total (n=34)	Intervention (n=17)	Control (n=17)	*P*-value
	Frequency (%); Mean ± SD; Median (IQR)			
Age of participant, years	49.32 ± 10.21	47 ± 10.37	51.65 ± 9.79	0.188
18 to 30	3 (8.82)	2 (11.76)	1 (5.88)	0.476
31 to 40	2 (5.88)	2 (11.76)	0	
41 to 50	9 (26.47)	5 (29.41)	4 (23.53)	
51 to 65	20 (58.82)	8 (47.06)	12 (70.59)	
Sex of participant				0.465
Male	23 (67.65)	13 (76.47)	10 (58.82)	
Female	11 (32.35)	4 (23.53)	7 (41.18)	
Educational attainment				0.136
Elementary	4 (11.76)	2 (11.76)	2 (11.76)	
High school	3 (8.82)	1 (5.88)	2 (11.76)	
Vocational	17 (50)	6 (35.29)	11 (64.71)	
College	10 (29.41)	8 (47.06)	2 (11.76)	
Work before				0.465
Manual labor	23 (67.65)	10 (58.82)	13 (76.47)	
Professional/office job	11 (32.35)	7 (41.18)	4 (23.53)	
Work post-stroke				1.000
Unemployed	29 (85.29)	15 (88.24)	14 (82.35)	
Employed	5 (14.71)	2 (11.76)	3 (17.65)	
Handedness before stroke				1.000
Left	3 (8.82)	2 (11.76)	1 (5.88)	
Right	31 (91.18)	15 (88.24)	16 (94.12)	
Played instrument before	11 (32.35)	5 (29.41)	6 (35.29)	1.000
Played guitar before	11 (32.35)	5 (29.41)	6 (35.29)	1.000
Comorbidities				
Hypertension	25 (73.53)	10 (58.82)	15 (88.24)	0.118
Diabetes mellitus	8 (23.53)	4 (23.53)	4 (23.53)	1.000
Heart disease	5 (14.71)	4 (23.53)	1 (5.88)	0.335
Others	9 (26.47)	1 (5.88)	8 (47.06)	**0.017**
Type of Stroke				1.000
Infarct	24 (70.59)	12 (70.59)	12 (70.59)	
Bleed	10 (29.41)	5 (29.41)	5 (29.41)	
Length of time of stroke, years	3 (0.83 to 6.92)	1.83 (0.92 to 5.75)	3.67 (0.75 to 11.58)	0.534
Hand impairment				1.000
Right	19 (55.88)	10 (58.82)	9 (52.94)	
Left	15 (44.12)	7 (41.18)	8 (47.06)	
Compliance				
PGH	34 (100)	17 (100)	17 (100)	-
Home	22 (64.71)	12 (70.59)	10 (58.82)	0.721

finger flexion at the proximal interphalangeal joint (PIP) (p = 0.003) and greater measured active range of motion in elbow extension (p = 0.034). In the post-treatment observation, participants in both groups showed statistically significant difference in active finger MCP flexion (p = 0.040), finger PIP flexion (p < 0.001), and thumb MCP flexion (p = 0.009). The rest were not statistically significant. Comparison of the pre-treatment to the post-treatment results among those within the control group and among those within the intervention group were shown in Appendix A. Guitar lessons resulted in statistically significant improvements in active ROM measurements except for finger PIP extension (p = 0.708) and wrist flexion (p = 0.087). The control group resulted in statistically significant improvement in active ROM for all measurements. Further analysis showed that a more statistically significant improvement was noted in the intervention group as seen in the active finger MCP flexion (p = 0.010 vs p = 0.015), finger PIP flexion (p = 0.026 vs p = 0.046), thumb MCP flexion (p = 0.003 vs p = 0.039), and wrist RD (p < 0.001 vs p = 0.002). Active wrist extension showed equivalent improvement in range of motion in both intervention and control groups (p < 0.001).

Table 2 shows comparison of actual change of active range of motion in the pre- and post-treatment between the control and intervention groups. There was no noted statistically significant difference in measure of active hand ROM between intervention and control groups. However, there was greater improvement in active shoulder abduction with the control group than with intervention group (median [IQR] 10 [5 to 25] vs 24 [12 to 50], p = 0.027).

Appendix B shows the comparison of passive range of motion between control and intervention groups prior to and after performance of treatment. The pre-treatment data for both groups showed a significant difference only in forearm supination (p = 0.036). The rest were not statistically significant. No statistically significant difference was noted in post-treatment passive range of motion of affected upper extremity. Comparison of pre- to post-treatment passive range of motion results among those within the control group and among those within the intervention group were shown in Appendix B. Guitar lessons resulted in statistically significant improvements in passive ROM measurements of wrist flexion (p = 0.009) and extension (p = 0.005), wrist RD (p = 0.003), elbow flexion (p = 0.003), and shoulder abduction (p = 0.021). Meanwhile, the control group resulted in statistically significant improvement in passive ROM of wrist flexion (p = 0.005) and extension (p = 0.003), UD (p = 0.001), RD (p = 0.004), and elbow flexion (p = 0.003). Further analysis showed that a more statistically significant improvement was noted in the intervention group as seen in the passive wrist RD (p = 0.003 vs p = 0.004) and shoulder abduction (p = 0.021 vs p = 0.134). Passive elbow flexion showed equivalent improvement in range of motion in both intervention and control groups (p = 0.003).

Table 3 shows the comparison of actual change of passive range of motion in the pre- and post-treatment between the control and intervention groups. There is no noted statistically significant difference between the two groups.

Hand function was evaluated and measured using different objective tools. The *Beery-Buktenica Developmental Test of Visual-Motor Integration* measures visual perception (ability to see and interpret those in the environment), motor coordination (ability to control movements with precision), and hand-eye coordination (precision of motion towards or away from visual stimulus) of participants across all ages to eventually measure how an individual can integrate their visual and motor abilities.[10] The *Jebsen-Taylor Hand Function Test* measures the capacity of the hand to function as required in performing activities of daily living.[11] The *Purdue Pegboard Test of Manual Dexterity* measures fine and gross motor dexterity as well as coordination of the hands and rest of the upper extremities.[12] Muscle strength of the hands for grip and pinch was measured using dynamometer and pinch gauge.

Appendix C shows the comparison of the pre- and post-treatment results of the different hand function evaluation between the control and intervention groups. Pre-treatment hand function evaluation showed no statistically significant difference between the two groups. In the post-treatment hand function evaluation, the intervention group showed significantly greater function in *visual perception* (p = 0.022). Comparison of the pre-treatment to the post-treatment hand function evaluation results among those within the control group and among those within the intervention group were shown in Appendix C. Guitar lessons resulted in statistically significant improvements in writing (p = 0.017), picking small objects (p = 0.005), simulated feeding (p = 0.005), stacking checkers (p = 0.007), holding large light (p = 0.007)

Table 2. Actual Change of Range of Motion (Active)

	Total (n=34)	Intervention (n=17)	Control (n=17)	*P*-value
	Median (IQR)			
Finger				
MCP Flexion	0 (0 to 10)	3 (0 to 15)	0 (0 to 8)	0.341
MCP Extension	0 (0 to 15)	0 (0 to 12)	0 (0 to 45)	0.354
PIP Flexion	0 (0 to 2)	0 (0 to 2)	0 (0 to 10)	0.877
PIP Extension	0 (0 to 10)	0 (0 to 0)	0 (0 to 0)	0.092
Thumb				
MCP Flexion	0 (0 to 6)	2 (0 to 6)	0 (0 to 6)	0.543
MCP Extension	1 (0 to 18)	0 (0 to 5)	10 (0 to 24)	0.277
Wrist				
Flexion	9 (0 to 14)	2 (0 to 12)	10 (6 to 14)	0.094
Extension	9.5 (5 to 16)	8 (5 to 13)	10 (5 to 18)	0.678
UD	7 (0 to 10)	6 (0 to 10)	8 (4 to 10)	0.234
RD	4 (0 to 10)	4 (0 to 9)	4 (0 to 10)	0.767
Forearm				
Supination	10 (0 to 30)	14 (0 to 30)	10 (0 to 22)	0.972
Pronation	0 (0 to 8)	0 (0 to 0)	0 (0 to 8)	0.625
Elbow				
Flexion	5.5 (0 to 10)	4 (0 to 8)	7 (0 to 12)	0.301
Extension	0 (0 to 12)	0 (0 to 0)	4 (0 to 12)	0.153
Shoulder				
Abduction	18 (5 to 40)	10 (5 to 25)	24 (12 to 50)	**0.027**

Table 3. Actual Change of Range of Motion (Passive)

	Total (n=34)	Intervention (n=17)	Control (n=17)	*P*-value
	Median (IQR)			
Finger				
MCP Flexion	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)	0.255
MCP Extension	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)	0.317
PIP Flexion	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)	0.317
PIP Extension	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)	0.317
Thumb				
MCP Flexion	0 (0 to 0)	0 (0 to 0)	0 (0 to 8)	0.105
MCP Extension	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)	0.180
Wrist				
Flexion	0 (0 to 8)	0 (0 to 5)	0 (0 to 8)	0.704
Extension	5 (0 to 10)	0 (0 to 5)	10 (0 to 12)	0.078
UD	2 (0 to 8)	0 (0 to 8)	7 (0 to 9)	0.107
RD	2 (0 to 5)	2 (0 to 5)	3 (0 to 6)	0.591
Forearm				
Supination	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)	0.295
Pronation	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)	1.000
Elbow				
Flexion	2 (0 to 5)	2 (0 to 4)	2 (0 to 6)	0.402
Extension	0 (0 to 0)	0 (0 to 0)	0 (0 to 0)	-
Shoulder				
Abduction	10 (0 to 20)	8 (0 to 10)	18 (0 to 52)	0.143

and large heavy objects (p = 0.003), hand grip strength (p = 0.003), and pinch strength [lateral pinch (p = 0.002), tip (p = 0.011), and 3-jaw (p < 0.001)]. Further analyzing results, more statistically significant improvement was noted in the intervention group: holding large heavy objects (p = 0.003 vs p = 0.025), lateral pinch strength (p = 0.002 vs p = 0.015), and 3-jaw pinch strength (p < 0.001 vs p = 0.003).

Table 4 shows comparison of the actual change in the pre- and post-treatment hand function evaluation between the control and intervention groups. No statistically significant differences between groups were observed in hand function except for noted greater improvement with the control group than with the intervention group in motor coordination (median [IQR] 0 [-1 to 0] vs 1 [1 to 5], p = 0.004), tip (median [IQR] 0.33 [0 to 0.75] vs 1 [0.58 to 1.5], p = 0.006), and 3-jaw (median [IQR] 0.5 [0 to 0.92] vs 1.08 [0.41 to 2], p = 0.043) pinch strength tests.

Patient satisfaction survey was accomplished by each participant after the 8-day treatment session. According to the gathered results from this survey, higher mean scores were noted in the control group than in the intervention group (Table 5). However, there was no noted statistically significant difference in satisfaction felt by the participants in both control and intervention groups except for the following items: *Is the treatment session easy to understand and perform?* (p = 0.034), *Are you encouraged to return to the hospital to do the next treatment sessions?* (p =0.044), and *Do you plan to continue with this program?* (p = 0.034). Strong agreement to these three items in the control group may be due to the fact that the traditional occupational therapy sessions were more familiar and related to their activities of daily living.

At the end of the satisfaction survey, all participants were asked if they would recommend the program to others with chronic stroke. In both groups, they all answered YES. The summary of responses of the participants on why they will recommend the specific treatment program they have received to other chronic stroke patients were tabulated in Table 6.

DISCUSSION

Stroke occurs when blood flow to any part of the brain is compromised whether due to blockage (ischemia or infarct) or breakage (hemorrhage) of the blood vessels supplying it. Evidence of impairment depends on the affected area of the brain, wherein up to 87% of stroke survivors sustain some degree of hand impairment.[13] According to a 2007 study, recovery after stroke was defined as "some recovery of motor control after stroke occurring most rapidly during the first three months and usually plateauing by six months. Yet, 40% to 80% of all stroke survivors have incomplete functional recovery of the upper extremity at 3 to 6 months post-stroke".[13] Hence, rehabilitation is done to post-stroke patients at the earliest possible time to assist in providing structured recovery of impairments. This is to take advantage of the crucial period of increased plasticity of the brain at the early stage of stroke recovery which lasts up to approximately three months.[14]

Repetitive exercises are part of rehabilitation management done in every therapeutic session to take advantage of neuroplasticity. Neuroplasticity is defined as the ability of the brain to be remodeled in response to the stimulation it received.[15] These repetitive exercises therefore promote reorganization of cortical maps in the primary motor and sensorimotor cortex in the lesioned hemisphere. The exercises included in the guitar lesson created by the proponents of the study were patterned from the different occupational therapy exercises of the hand. These include range of motions

Table 4. Actual Change of Hand Function Evaluation from Pre-treatment to Post-treatment

	Total (n=34)	Intervention (n=17)	Control (n=17)	*P*-value
	Median (IQR)			
Beery-Buktenica Developmental Test of Visual-Motor Integration				
Beery	1.5 (-1 to 2)	1 (-1 to 2)	2 (0 to 2)	0.613
Visual perception	1 (-2 to 1)	1 (-1 to 2)	0 (-2 to 1)	0.294
Motor coordination	1 (0 to 3)	0 (-1 to 0)	1 (1 to 5)	**0.004**
Jebsen-Taylor Hand Function test				
Writing	-2.47 (-11.6 to 0)	-2.07 (-18.87 to 0)	-2.86 (-5.53 to 0)	0.543
Turning card	-1.47 (-10 to 0.73)	-1.45 (-11.29 to 0)	-1.48 (-8.93 to 50.76)	0.535
Small objects	-0.89 (-5.15 to 0)	-0.79 (-12.24 to 0)	-0.98 (-1.98 to 0)	0.391
Simulated feeding	-3.09 (-28.45 to 0)	-3.65 (-7.4 to 0)	-2.74 (-28.45 to 0)	0.717
Checkers	-1.45 (-3.25 to 0)	-2.41 (-3.26 to 0)	0 (-2.64 to 0)	0.207
Large light objects	0 (-1.98 to 0)	-0.42 (-1.57 to 0)	0 (-2.93 to 0)	0.242
Large heavy objects	-0.27 (-1.98 to 0)	-0.54 (-1.55 to 0)	0 (-1.98 to 0)	0.986
Purdue Pegboard test of Manual Dexterity				
Right	1 (0 to 1)	1 (0 to 1)	1 (0 to 2)	0.122
Left	0.5 (0 to 2)	0 (0 to 1)	1 (0 to 2)	0.155
Bilateral	0 (0 to 1)	0 (0 to 1)	0 (0 to 1)	0.403
Right + Left + Bilateral	1 (0 to 3)	1 (0 to 3)	2 (1 to 3)	0.072
Assembly	0 (0 to 2)	0 (0 to 2)	0 (0 to 1)	0.808
Hand grip strength test, kg/F	1.33 (0.33 to 3)	1.33 (0.33 to 2.67)	1.34 (0.67 to 3)	0.478
Pinch strength test, kg/F				
Lateral	0.71 (0.25 to 1.25)	0.67 (0.25 to 1)	0.83 (0.25 to 1.58)	0.642
Tip	0.71 (0.08 to 1.16)	0.33 (0 to 0.75)	1 (0.58 to 1.5)	**0.006**
3-Jaw	0.58 (0.17 to 1.58)	0.5 (0 to 0.92)	1.08 (0.41 to 2)	**0.043**

Table 5. Satisfaction Survey

	Intervention (n=17)	Control (n=17)	*P*-value
	Mean ± SD		
Is the treatment session easy to understand and perform?	4.06 ± 1.56	4.93 ± 0.25	**0.034**
Is each session of the treatment program tiring?	3.71 ± 1.53	4.13 ± 1.20	0.391
Are you interested in doing the treatment program?	4.24 ± 1.44	4.88 ± 0.50	0.102
Are you encouraged to return to the hospital to do the next treatment sessions?	3.65 ± 1.73	4.63 ± 0.72	**0.044**
Are you encouraged to do each homework assigned by your therapist?	4.44 ± 1.21	4.94 ± 0.25	0.116
Are you encouraged to practice more beyond the homework assigned by your therapist?	4.31 ± 1.4	4.81 ± 0.40	0.180
Do you plan to continue with this program?	3.82 ± 1.7	4.81 ± 0.54	**0.034**
Overall satisfaction	4.47 ± 1.18	4.94 ± 0.25	0.131

Table 6. Summary of Responses

Control Group (Occupational Therapy)	Intervention Group (Guitar Lessons)
• *dahil napakahusay (may magagawa ang kamay ko)* • *malaking tulong lalo na sa mga walang budget para makatherapy* • *para matutunan ang tamang pagte-therapy* • *para makatulong sa ibang katulad naming na-stroke na mahina igalaw at para lumakas*	• *dahil maganda at maayos* • *maganda yung treatment sa gitara* • *to improve hand function* • *it's fun* • *dahil malaking tulong po ito sa pagsara bukas ng kamay na may panghina, nakatulong din po ito sa pagbilis ng pag galaw o pagdampot ng mahina kong kamay* • *nabawasan ng 80% ang paninigas* • *para makatulong sa mga gawaing bahay sa araw-araw* • *nakalimot ka sa iyong karamdaman kahit papaano*

of the joints of the upper extremity which were incorporated into the different hand movements used in playing the guitar.

Principles of neuroplasticity include use it or lose it (stimulation of brain function leads to gain of abilities), use it and improve it (training of a specific brain function leads to improvement of abilities), specificity (nature of training experience affects nature of brain change), repetition matters (change occurs with sufficient repetition), intensity matters (change occurs as a result of intense training), time matters (different forms of change at different times during training), salience matters (meaningful training experience causes a change in the brain), age matters (younger brains have better training-induced changes in the brain), transference (training for a specific function can lead to learning similar skills), and interference (changes in the brain due to bad habits or incorrect performance interferes with learning good habits and skills).[16,17]

This study investigated the possible use of a specific guitar lesson as a tool in hand rehabilitation of chronic stroke patients. During the conduct of the study, varying degrees of improvements in hand function were observed in both groups. Results of the inter- and intragroup evaluation of pre- and post-treatment (Appendices A, B, and C) as well as the comparison of actual change from pre- to post-treatment between groups (Tables 2, 3, and 4) showed comparable use of guitar in restoring hand function among chronic stroke patients. The noted improvement in measured active and passive ROM between control and intervention groups (inter-group comparison and actual difference) did not show statistically significant difference which may show comparable results with either treatment. Statistically significant difference in intra-group data (comparison of pre- and post-treatment data within each group) in both active and passive ROM may further support the comparable effect of either treatment. In Table 2, it showed a greater improvement in active shoulder abduction with the control group than with intervention group. The hand movements found in each specific guitar lesson used in this study were formulated to facilitate joint movements used in occupational therapy. However, active shoulder abduction to facilitate overhead activities are not usually seen during guitar playing. Shoulder and scapular mobilization and stretching are part of the intervention in occupational therapy especially if the individual has tightness of the shoulder that limits hand function and mobility to perform daily activities.

Intra-group evaluation of the improvement in hand function (as measured by the Jebsen-Taylor hand function test, grip and pinch strength) of those in the intervention group were observed but more significantly in holding large objects and in lateral and 3-jaw pinch strength. However, in the intra-group evaluation of dexterity (using Purdue Pegboard test) and motor coordination (using Beery-Buktenica), a more statistically significant difference was seen for those in the control than in the intervention group. This proves the strength and superiority of performing exercises under the supervision of licensed occupational therapists. Looking into the results of the inter-group analysis and measure of actual change of motor coordination, there is an observed statistically significant difference in the control group which may be due to variety in spatial activities (such as activities of daily living) involved in occupational therapy which may be limited with playing the guitar. With the results from the intra-group analysis and measure of actual change for hand dexterity, the absence of statistically significant difference in this function may support the comparable effect with either of the treatments performed.

The intra-group analysis of both groups showed statistically significant difference in pinch strength. However, a more statistically significant difference in the intervention group for the lateral pinch ($p = 0.002$ vs $p = 0.015$) and 3-jaw pinch ($p < 0.001$ vs $p = 0.003$) strength was observed. Looking into the actual change, a greater improvement within the control group for tip-to-tip pinch (median [IQR] 0.33 [0 to 0.75] vs 1 [0.58 to 1.5], $p = 0.006$), and 3-jaw pinch (median [IQR] 0.5 [0 to 0.92] vs 1.08 [0.41 to 2], $p = 0.043$) strength tests. Although guitar lessons done by the intervention group may produce comparable improvement in grip and pinch strength, exercises in occupational therapy use putties and webs which specifically target hand strength.

Active music therapy was used in this study. Stroke participants performed activities with the impaired hand while doing other activities to produce music. This includes listening to the instruction, listening to the music piece being taught, following and practicing the different techniques of guitar playing, reading music cues, memorizing and playing the whole song. International studies on music and rehabilitation showed that through this set of activities, varying parts of the brain undergo some degree of remodeling that stimulated improvements in the patients' speech, hand function, cadence, and behavior.[14,18-20] The active playing of guitar could have tapped into the principles of neuroplasticity such as salience matters and transference. Although guitar playing is not a task-specific activity (as most of the participants in the intervention group did not have a history of guitar playing), the repetitive motion of the fingers, wrist, forearm, elbow, and shoulder involved a mass practice of movements that eventually led to some degree of improvement.[13]

During the conduct of this specific guitar lesson, sets of guitar pieces were provided. Upper extremity exercises were integrated into movements that were used in guitar playing. Different hand movements were repeated into sets that each participant in the control group performed. Additionally, most of the participants requested the guitar instructors to provide them with guitar pieces of their favorite songs which the instructors accommodated by modifying the chord shapes and progressions assigned for the unaffected hand while keeping the same playing techniques for the affected hand subject to therapy. These songs were adjusted in terms of tempo and rhythmic pattern to match the prescribed guitar exercises according to the officially approved project-

produced guitar instruction protocol. With this, an enriched environment could have further facilitated improvement of the impaired hand as it may have boosted the recovery of sensorimotor function and further promote neuroplasticity.[21] The quality of music produced during active guitar playing with the impaired hand may have further increased the excitability in the brain (motor cortex, auditory cortex, cerebellum) leading also to brain function remodeling and motor function integration.[14,18] Aside from the structural and physiologic effects of music, its power in stimulating an individual could have brought the 11.8% improvement in compliance to home exercises for those in the intervention group.[18]

One of the participants who was randomly grouped in the intervention group was a former musician. After the conduct of the guitar lessons from this study, improvements in all of her post-treatment results were markedly increased, if not doubled. This showed parallelism with the discussions in varying studies on music and rehabilitation. According to Rodrigues et al., structural and functional brain development were more evident in musicians than in non-musicians.[19] Motor and somatosensory cortices as well as cerebellum were shown in fMRI to be more developed. Even left and right hemispheres in musicians were more symmetric as compared to nonmusicians. This participant's remarkable post-treatment improvement could be explained by this phenomenon.

In reviewing the patient feedback survey, the scores in the intervention group are noted to be slightly lower across all components than those of the control group. Although participants from both groups answered YES to recommending their respective treatment to others, the lower scores in the intervention group may be attributed to other factors such as the new, unfamiliar setup of the intervention group using guitar lessons in rehabilitation. It must also be noted that there is a much wider standard deviation (minimum of ± 1.18, maximum of ± 1.73) across all items in the results from the intervention group which suggests more varied experiences within the intervention group as compared to the control group (minimum of ± 0.25, maximum of ± 1.20). It is possible that the past musical experiences of participants may have had an effect on their reception towards the treatment.

CONCLUSION

The use of structured treatment program such as this specific guitar lesson, with the supervision of guitar instructors, could improve function of an impaired unilateral hand in those with chronic stroke that is comparable with those who underwent traditional occupational therapy. This may be helpful in areas with limited access to rehabilitation facilities and occupational therapy services. This may also be used as a continuing activity of chronic stroke patients at home to further improve or to preserve their current hand function.

Limitations of the Study

Study participants who consented to join the study were mostly members of the Stroke Support Group of the Philippine General Hospital. They were mostly from within the City of Manila and nearby municipalities. Other potential participants who were not member of the group were reluctant to join the study due to several considerations such as inaccessibility of the study site due to multiple rides needed, unavailability of companion due to work or school schedule, and opportunity cost for the patient and caregiver. This may have caused to produce selection bias.

Recommendations

In this study, the results showed less improvement in the manual dexterity, coordination, and pinch strength of those who underwent guitar lessons. To address this, future studies may require participants in the intervention group to go through the more advanced guitar exercises (arpeggios, scales, tremolo, and advanced strumming such as rasgueado) that adds finger independence to its target outcomes. These advanced techniques require a longer program duration (more than eight sessions) to accomplish.

Future protocol development may be necessary to investigate reproducibility of this set of GTARA exercises when supervised and facilitated by other professionals. Also, we recommend this to be conducted remotely, synchronous or asynchronous, to assess its feasibility in bridging the gap in the burden of care of stroke patients and to look into the satisfaction and compliance of these patients in using the GTARA exercises. "Social media" or a virtual platform may be used in the conduct of this study considering that rehabilitation services and professionals are still lacking and inaccessible in the country.

Lastly, functional neuroimaging studies may be included in future studies to monitor effects of this specific guitar exercise on the brain (structural or chemical change, duration of effect, effect of music to length of effect, etc.).

Acknowledgments

The proponents of the study would like to express their deepest appreciation to all the stroke participants and their caregivers who gave their time willingly as well as to the Department of Strings and Chamber Music, College of Music of UP Diliman and to the Department of Rehabilitation Medicine of UP-PGH for their unwavering support. Special thanks to Jeff Streegan for his invaluable contribution to this study in the field of occupational therapy.

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

All authors declared no conflicts of interest.

Funding Source

Funding for the conduct of this study was granted by DOST-PCHRD as stated in the Memorandum with Series Number 1072 A-21/FRN.

REFERENCES

1. Lee KS, Jung MC. Ergonomic evaluation of biomechanical hand function. Saf Health Work. 2015 Mar; 6(1):9-17. doi:10.1016/j.shaw.2014.09.002. PMID: 25830064; PMCID: PMC4372184
2. Philippine Statistics Authority, Occupational injuries involving upper extremities [Internet]. 2020 [cited 2023 Feb]. Available from: http://psa.gov.ph.
3. World Health Organization, Stroke: A global response is needed [Internet]. 2017 [cited 2023 Jan]. Available from: http://www.who.int/bulletin/volumes/94/9/16-181636/en/.
4. Collantes ME, Navarro J, Belen A, Gan R. Stroke systems of care in the Philippines: Addressing gaps and developing strategies. Front Neurol. 2022 Nov 24;13:1046351. doi: 10.3389/fneur.2022.1046351. PMID: 36504651; PMCID: PMC9729337.
5. Collantes MV, Zuñiga YH, Granada CN, Uezono DR, De Castillo LC, Enriquez CG, et al. Current state of stroke care in the Philippines. Front Neurol. 2021 Aug 17; 12:665086. doi: 10.3389/fneur.2021.665086. PMID: 34484093; PMCID: PMC8415827.
6. Chong HJ, Cho SR, Jeong E, Kim SJ. Finger exercise with keyboard playing in adults with cerebral palsy: a preliminary study. J Exerc Rehabil. 2013 Aug 31;9(4):420–5. doi: 10.12965/jer.130050. PMID: 24278895; PMCID: PMC3836538.
7. Lim HA, Miller K, Fabian C. The effects of therapeutic instrumental music performance on endurance level, self-perceived fatigue level, and self-perceived exertion of inpatients in physical rehabilitation. J Music Ther. 2011 Summer; 48(2):124–48. doi: 10.1093/jmt/48.2.124. PMID: 21938889.
8. Ligaya K, Ignacio S. Improving pincer grasp and prehension in a chronic stroke patient through music therapy using guitar: a case report. PARM Proceedings. 2018 Nov;10(2):40-4.
9. Kiran S. What is the nature of poststroke language recovery and reorganization? ISRN Neurol. 2012:2012:786872. doi: 10.5402/2012/786872. PMID: 23320190 PMCID: PMC3540797.
10. Pearson Assessments, Beery-Buktenica Developmental Test of Visual-Motor Integration: Sixth Edition [Internet]. 2010 [cited 2023 Mar]. Available from: https://www.pearsonassessments.com/store/usassessments/en/Store/Professional-Assessments/Academic-Learning/Brief/Beery-Buktenica-Developmental-Test-of-Visual-Motor-Integration-%7C-Sixth-Edition/p/100000663.html.
11. Shirley Ryan Ability Lab, Jebsen Hand Function Test [Internet]. 2023 [cited 2023 Ma]. Available from: https://www.sralab.org/rehabilitation-measures/jebsen-hand-function-test.
12. Lafayette Instrument, Purdue Pegboard™ [Internet]. 2023 [cited 2023 Mar]. Available from: https://lafayetteevaluation.com/products/purdue-pegboard.
13. Knutson JS, Harley MY, Hisel TZ, Chae J. Improving hand function in stroke survivors: a pilot study of contralaterally controlled functional electric stimulation in chronic hemiplegia. Arch Phys Med Rehabil. 2007 Apr;88(4):513-20. doi: 10.1016/j.apmr.2007.01.003. PMID: 17398254; PMCID: PMC3961574.
14. Xu C, He Z, Shen Z, Huang F. Potential benefits of music therapy on stroke rehabilitation. Oxid Med Cell Longev. 2022 Jun 15;2022:9386095. doi: 10.1155/2022/9386095. PMID: 35757506; PMCID: PMC9217607.
15. Hallet M. Neuroplasticity and Rehabilitation - Guest Editorial [Internet]. JRRD. 2005;42(4). 2005 [cited 2023 Feb]. Available from: https://www.rehab.research.va.gov/jour/05/42/4/pdf/hallett.pdf
16. Centre For Neuro Skills, Ten Principles of Neuroplasticity [Internet]. 2023 [cited 2023 Mar]. Available from: https://www.neuroskills.com/brain-injury/neuroplasticity/ten-principles-of-neuroplasticity/.
17. Center for Independence through Conductive Education,10 Principles of Neuroplasticity: Part 1 [Internet]. 2018 [cited 2023 Mar]. Available from: https://www.cfimove.org/.
18. Rodrigues AC, Loureiro MA, Caramelli P. Musical training, neuroplasticity and cognition. Dement Neuropsychol. 2010 Oct-Dec; 4(4):277-86. doi: 10.1590/S1980-57642010DN40400005. PMID: 29213699; PMCID: PMC5619060.
19. Neuroplasticity - Insights of Neural Reorganization, Music and Brain Plasticity: How Sounds Trigger Neurogenerative Adaptations [Internet]. 2018 [cited 2023 Mar]. Available from: https://www.intechopen.com/chapters/59437
20. Eschmann H, Héroux ME, Cheetham JH, Potts S, Diong J. Thumb and finger movement is reduced after stroke: An observational study. PLoS One. 2019 Jun 12;14(6):e0217969. doi: 10.1371/journal.pone.0217969. PMID: 31188859; PMCID: PMC6561636.
21. Han Y, Yuan M, Guo YS, Shen XY, Gao ZK, Bi X. The role of enriched environment in neural development and repair. Front Cell Neurosci. 2022 Jul 21;16:890666. doi: 10.3389/fncel.2022.890666. PMID: 35936498; PMCID: PMC9350910.

APPENDICES

Appendix A. Range of Motion (Active), in Degrees°

	Intervention (n=17)	Control (n=17)	*P*-value
	Median (IQR)		
Active – Pre-treatment			
Finger			
MCP Flexion	74 (58 to 90)	90 (80 to 90)	0.052
MCP Extension	80 (48 to 90)	60 (0 to 90)	0.240
PIP Flexion	90 (90 to 100)	110 (100 to 110)	**0.003**
PIP Extension	100 (65 to 110)	70 (10 to 110)	0.213
Thumb			
MCP Flexion	22 (18 to 30)	50 (28 to 60)	0.053
MCP Extension	20 (0 to 40)	0 (0 to 30)	0.357
Wrist			
Flexion	38 (30 to 52)	46 (28 to 58)	0.581
Extension	22 (8 to 35)	15 (0 to 40)	0.641
UD	18 (12 to 21)	18 (0 to 22)	0.794
RD	8 (0 to 12)	10 (8 to 16)	0.317
Forearm			
Supination	70 (42 to 90)	60 (28 to 90)	0.412
Pronation	90 (80 to 90)	90 (80 to 90)	0.898
Elbow			
Flexion	134 (128 to 150)	125 (110 to 136)	0.123
Extension	150 (150 to 150)	140 (110 to 150)	**0.034**
Shoulder			
Abduction	121 (85 to 145)	90 (75 to 110)	0.157
Active – Post-treatment			
Finger			
MCP Flexion	80 (70 to 90)	90 (90 to 90)	**0.040**
MCP Extension	75 (70 to 90)	90 (60 to 90)	0.765
PIP Flexion	92 (90 to 100)	110 (110 to 110)	**<0.001**
PIP Extension	100 (70 to 110)	110 (40 to 110)	0.894
Thumb			
MCP Flexion	30 (20 to 40)	60 (32 to 60)	**0.009**
MCP Extension	38 (5 to 45)	38 (12 to 58)	0.677
Wrist			
Flexion	40 (38 to 50)	60 (42 to 68)	0.064
Extension	40 (11 to 50)	20 (12 to 54)	0.717
UD	18 (15 to 30)	30 (10 to 30)	0.657
RD	14 (10 to 20)	20 (18 to 20)	0.096
Forearm			
Supination	90 (80 to 90)	80 (60 to 90)	0.328
Pronation	90 (90 to 90)	90 (90 to 90)	0.310
Elbow			
Flexion	140 (132 to 150)	135 (131 to 150)	0.611
Extension	150 (150 to 150)	150 (150 to 150)	0.364
Shoulder			
Abduction	145 (100 to 170)	120 (101 to 142)	0.416

	Intervention (n=17)	Control (n=17)
	P-value	
Comparison from Pre-treatment to Post-treatment		
Finger		
MCP Flexion	**0.010**	**0.015**
MCP Extension	**0.045**	**0.009**
PIP Flexion	**0.026**	**0.046**
PIP Extension	0.708	**0.005**
Thumb		
MCP Flexion	**0.003**	**0.039**
MCP Extension	**0.009**	**0.002**
Wrist		
Flexion	0.087	**0.001**
Extension	**<0.001**	**<0.001**
UD	**0.006**	**<0.001**
RD	**<0.001**	**0.002**
Forearm		
Supination	**0.002**	**0.001**
Pronation	**0.046**	**0.026**
Elbow		
Flexion	**0.001**	**<0.001**
Extension	**0.046**	**0.011**
Shoulder		
Abduction	**0.004**	**0.003**

Appendix B. Range of Motion (Passive), in Degrees°

	Intervention (n=17)	Control (n=17)	*P*-value
	Median (IQR)		
Passive – Pre-treatment			
Finger			
MCP Flexion	90 (80 to 90)	90 (90 to 90)	0.340
MCP Extension	90 (90 to 90)	90 (90 to 90)	0.317
PIP Flexion	110 (90 to 110)	110 (100 to 110)	1.000
PIP Extension	110 (100 to 110)	110 (100 to 110)	0.966
Thumb			
MCP Flexion	60 (50 to 60)	50 (52 to 60)	0.852
MCP Extension	60 (50 to 60)	60 (60 to 60)	0.557
Wrist			
Flexion	74 (68 to 80)	80 (64 to 80)	0.524
Extension	70 (65 to 80)	70 (55 to 70)	0.125
UD	30 (27 to 30)	24 (22 to 30)	0.222
RD	18 (12 to 20)	17 (14 to 20)	0.901
Forearm			
Supination	90 (90 to 90)	90 (80 to 90)	**0.036**
Pronation	90 (90 to 90)	90 (90 to 90)	-
Elbow			
Flexion	145 (142 to 150)	142 (140 to 150)	0.367
Extension	150 (150 to 150)	150 (150 to 150)	-
Shoulder			
Abduction	158 (130 to 180)	140 (104 to 158)	0.239
Passive – Post-treatment			
Finger			
MCP Flexion	90 (80 to 90)	90 (70 to 90)	0.340
MCP Extension	90 (90 to 90)	90 (90 to 90)	0.317
PIP Flexion	110 (100 to 110)	110 (110 to 110)	1.000
PIP Extension	110 (100 to 110)	110 (110 to 110)	0.966
Thumb			
MCP Flexion	60 (60 to 70)	60 (50 to 60)	0.835
MCP Extension	60 (50 to 60)	60 (50 to 60)	0.966
Wrist			
Flexion	80 (72 to 80)	80 (75 to 80)	0.516
Extension	80 (70 to 80)	75 (70 to 80)	0.942
UD	30 (30 to 30)	30 (30 to 40)	0.340
RD	20 (20 to 30)	20 (18 to 20)	0.759
Forearm			
Supination	90 (90 to 90)	90 (80 to 90)	0.317
Pronation	90 (90 to 90)	90 (90 to 90)	-
Elbow			
Flexion	150 (145 to 150)	150 (142 to 150)	0.494
Extension	150 (150 to 150)	150 (150 to 150)	-
Shoulder			
Abduction	170 (138 to 180)	146 (129 to 175)	0.352

	Intervention (n=17)	Control (n=17)
	P-value	
Comparison from Pre-treatment to Post-treatment		
Finger		
MCP Flexion	0.317	0.084
MCP Extension	-	0.317
PIP Flexion	-	0.317
PIP Extension	-	0.317
Thumb		
MCP Flexion	0.517	0.117
MCP Extension	1.000	0.084
Wrist		
Flexion	**0.009**	**0.005**
Extension	**0.005**	**0.003**
UD	0.063	**0.001**
RD	**0.003**	**0.004**
Forearm		
Supination	-	0.303
Pronation	-	-
Elbow		
Flexion	**0.003**	**0.003**
Extension	-	-
Shoulder		
Abduction	**0.021**	0.134

Appendix C. Hand Function Evaluation

		Intervention (n=17)	Control (n=17)	*P*-value
		Median (IQR)		
Pre treatment				
Beery-Buktenica Developmental Test of Visual-Motor Integration	*(test score)*			
Beery		16 (6 to 24)	15 (10 to 19)	0.653
Visual perception		24 (23 to 26)	21 (20 to 25)	0.074
Motor coordination		12 (5 to 17)	7 (4 to 15)	0.377
Jebsen-Taylor Hand Function test	*(time in seconds)*			
Writing		52.68 (0 to 77.16)	61.1 (38.9 to 78.67)	0.433
Turning card		14.17 (5.9 to 22.64)	9.38 (0 to 25.59)	0.767
Small objects		12.26 (0 to 31.88)	10 (0 to 25.72)	0.385
Simulated feeding		15.55 (10 to 52.51)	14.93 (0 to 66)	0.903
Checkers		7.15 (0 to 16.14)	7.63 (0 to 11.97)	0.249
Large light objects		5.18 (0 to 11.87)	0 (0 to 15.42)	0.856
Large heavy objects		4.79 (0 to 11.97)	6.62 (0 to 17.3)	0.623
Purdue Pegboard test of Manual Dexterity	*(number of pieces)*			
Right		6 (0 to 12)	4 (0 to 9)	0.440
Left		8 (3 to 11)	8 (2 to 10)	0.578
Bilateral		1 (0 to 4)	0 (0 to 1)	0.347
Right + Left + Bilateral		14 (11 to 21)	11 (8 to 13)	0.051
Assembly		8 (0 to 12)	0 (0 to 10)	0.423
Hand grip strength test, kg/F		3.67 (1.33 to 9)	4 (2 to 7.67)	0.796
Pinch strength test, kg/F				
Lateral		3.5 (2.42 to 5.25)	3.17 (2.25 to 5.33)	0.877
Tip		2 (0 to 2.75)	0.67 (0 to 2)	0.252
3-Jaw		2.42 (1.08 to 3.25)	1.83 (0 to 2.5)	0.320
Post treatment				
Beery-Buktenica Developmental Test of Visual-Motor Integration	*(test score)*			
Beery		16 (14 to 20)	17 (11 to 21)	0.665
Visual perception		24 (23 to 26)	22 (21 to 23)	**0.022**
Motor coordination		11 (4 to 15)	12 (6 to 16)	0.730
Jebsen-Taylor Hand Function test	*(time in seconds)*			
Writing		44.17 (0 to 57.75)	50.8 (35.2 to 116.4)	0.191
Turning card		10.5 (4.37 to22.39)	19.77 (11.2 to 86.1)	0.076
Small objects		11.69 (0 to 25.21)	13.25 (0 to 20.57)	0.986
Simulated feeding		10.72 (6.7 to 19.56)	33.53 (9.44 to 76.2)	0.116
Checkers		4.7 (0 to 11.15)	5.96 (0 to 10.54)	0.902
Large light objects		3.87 (0 to 8.97)	4.92 (0 to 11.23)	0.676
Large heavy objects		4.79 (0 to 11.97)	4.64 (0 to 12.5)	0.501
Purdue Pegboard test of Manual Dexterity	*(number of pieces)*			
Right		6 (2 to 13)	6 (0 to 10)	0.566
Left		10 (2 to 12)	9 (2 to 13)	0.889
Bilateral		1 (0 to 3)	0 (0 to 2)	0.575
Right + Left + Bilateral		15 (13 to 19)	13 (10 to 16)	0.147
Assembly		5 (0 to 14)	2 (0 to 10)	0.401
Hand grip strength test, kg/F		6.33 (2.33 to 12.33)	7.33 (3 to 12)	0.904
Pinch strength test, kg/F				
Lateral		4.75 (2.83 to 6.25)	3.67 (2.83 to 5.67)	0.642
Tip		2 (1.17 to 2.92)	2.17 (1.83 to 3)	0.692
3-Jaw		2.67 (1.67 to 3.67)	2.67 (1.67 to 3.75)	0.986

Appendix C. Hand Function Evaluation *(continued)*

	Intervention (n=17)	Control (n=17)
	P-value	
Comparison from Pre treatment to Post treatment		
Beery-Buktenica Developmental Test of Visual-Motor Integration		
Beery	0.329	**0.028**
Visual perception	0.302	0.867
Motor coordination	0.864	**0.001**
Jebsen-Taylor Hand Function test		
Writing	**0.017**	0.330
Turning card	0.061	0.925
Small objects	**0.005**	0.109
Simulated feeding	**0.005**	0.368
Checkers	**0.007**	0.382
Large light objects	**0.007**	0.900
Large heavy objects	**0.003**	**0.025**
Purdue Pegboard test of Manual Dexterity		
Right	0.096	**<0.001**
Left	0.309	**0.007**
Bilateral	0.408	0.051
Right + Left + Bilateral	0.057	**<0.001**
Assembly	0.199	**0.015**
Hand grip strength test, kg/F	**0.003**	**<0.001**
Pinch strength test, kg/F		
Lateral	**0.002**	**0.015**
Tip	**0.011**	**<0.001**
3-Jaw	**<0.001**	**0.003**

** - significant at 5% level of significance against pre-treatment*