Effectiveness of Graphomotricity as adjuvant for fine motor skills rehabilitation in traumatic radial nerve temporary disruptions due to trauma.

Alejandra Vega Torres[1], Sergio Reyes Toledo[2], Moisés Franco Valencia[3], Fabiola Niño de la Rosa[4], Raúl Fernando Martínez Martínez[5], Edith Doniz Alvarado[6]
[1]Physiotherapy intern from Universidad del Valle de México, Mexico City. Hospital General Xoco Orthopedics and Traumatology Service.
[2]Hospital General Xoco Orthopedic Service Attending Physician
[3]Hospital General Xoco Investigation Area Chief
[4]Unidad de Medicina Física y Rehabilitación, UMAE Hospital de Traumatología, Ortopedia y Rehabilitación "Dr. Victorio de la Fuente Narvaez" IMSS
[5]Cardiopulmonary Rehabilitation Specialist
[6]Universidad del Valle de México Campus Coyoacán. Children
alevega1993@gmail.com

Abbreviations
DASH = Disabilities of the Arm, Shoulder and Hand
MEPP= Fine motion stimulation cloth (Mantel para Estimulación de Prensión y Pinza fina)
TENS= Transcutaneous electrical nerve stimulation
MVA= Motor Vehicle Accident
GSW= Gunshot Wound
EMG= Electromyography

Abstract

Introduction: Radial nerve injury, often caused by humeral fractures, can disrupt mobility and functionality of the arm. Physiotherapy focused on function recovery are an essential component of radial nerve injury treatment. Graphomotricity has the purpose of educating and proofreading achievement of motor-perceptive processes which allow a better upper limb and fine motion domain. The present study aimed determine the efficacy of graphomotricity as a physiotherapy adjuvant for fine motor skill recovery after traumatic reversible nerve injuries. **Material and methods:** A non-randomized clinic essay was administered to twelve distal humeral fracture and radial nerve damage patients. Patients under 18 years old, with axonotmesis electromyographic data, or complete nerve injury were eliminated. Each patient completed 15 physical therapy sessions consisting of conventional treatment and fine motor skill stimulation with graphomotricity exercises. **Results:** After physical therapy and graphomotricity sessions, there was a significant ($p<0.001$) increase in average range of motion and strength. Additionally, there was a significant ($p<0.001$) decrease in average DASH scores. **Conclusion:** The present study suggests graphomotricity may be a valuable addition to conventional physical therapy for fine motor skill recovery in patients with traumatic radial nerve partial injury.

Key words: radial nerve, graphomotricity, nerve damage, physical therapy

Introduction

Traumatic peripheral nerve injuries are a major public health problem that can cause significant or permanent disability. These disabilities have been linked to a negative socioeconomic impact on the population (Miranda and Torres, 2016, p. 76; Castillo, Martínez, de la Garza, Elizondo and Guzmán, 2014, p.528).

On average, most traumatic peripheral nerve injuries occur at the age of 35 with a majority of the cases being male. The most affected areas in terms of anatomic location are the upper extremities.

The most commonly injured nerves in the upper limb include the ulnar, median and radial nerves (Miranda and Torres,2016, p. 77; Castillo et al.,2014, p. 528).

Humeral diaphysis factures are one of the leading causes of radial nerve injury. Approximately 3-5% of all skeletal fractures occur in the middle third of humeral diaphysis (Masson, 2012, p. 26). Etiologic factors include motor vehicle accident (MVA), penetrating injury, gunshot wound (GSW), sports-related injury, explosion-related injury, and compression (Miranda & Torres,2016, p. 77; Castillo et al. ,2014; Masson,2012, p. 28).

Peripheral nerve injuries can be divided, according to Seddon's and Sunderland's classifications, into three and five types respectively depending on the severity [neuropraxia and axonotmesis with recovery potential; and neurotmesis that needs healing surgical intervention] (Castillo et al, 2014, p. 530; Masson, 2012, p. 29). These classifications provide two key insights for peripheral nerve injury. First, they allow for an understanding of injury physiopathology. Second, these classifications aid in the establishment of probable diagnosis which helps determine an appropriate therapeutic approach.

Wrist drop deformity, due to loss of synergic action between wrist flexors and extensors, is the hallmark of a radial nerve injury. Additionally, radial nerve injury can cause loss of finger extension which can rob the patient of the ability to open the hand prior to initiating grasp. Loss of grip strength renders tasks requiring coordinated manual dexterity extremely difficult. (Ljungquist, Martineau,and Allan, 2015,p. 167; Prudden,2018, p. 3)

Aside from the traditional surgical options for treating peripheral nerve injuries, there are many new strategies for rehabilitation and physiotherapy. For example, kinetic therapy as well as electro and laser stimulation have shown great efficacy in recent research. Physiotherapy forms essential part of the treatment due to it's ability to restore normal function of muscles. (Suszynski, Marcol, Górka, 2015, p. 1770)

Kinetic therapy is used for neuromuscular reeducation. Research indicates it can reduce the risk of contractures and muscle atrophy. Additionally, kinetic therapy can increase control of voluntary movements and restore proprioceptive sensation. Electric stimulation plays an important role in the treatment of various neuromuscular dysfunctions. It is considered one of the most effective therapies when used in conjunction other treatments. Transcutaneous Electrical Nerve Stimulation (TENS) is the most common electric stimulation method for two reasons. First, it shortens the period of axonal nerve outgrowth. Second, TENS has a positive influence on regeneration processes by stabilizing the cholinergic receptors at the neuromuscular joint. Laser therapy increases ATP formation. The energy from hydrolysis of the newly formed ATP can be used by nerve cells to restore normal transmembrane potential. This restoration facilitates the generation of electrical impulses which restores nerve conduction. The application of laser beams improves microcirculation which brings in the nutrition needed to regenerate nerve cells. (Suszynski et al., 2015, p. 1771; Dumbraveanu, Suárez, Nicoleta, López, and Caballero, 2013, p. 108)

It is vital to avoid muscular atrophy and weakness, skin adhesion, edema and joint stiffness after peripheral nerve injury. Research shows the key to a full recovery is muscular strengthening and functional reeducation. (Zermeño et al., 2014, p. 24)

Motor abilities represent a significant portion of human development. The ability to write is one of the most prominent examples of motor skill development. Psychomotricity, particularly Graphomotricity, study the training process to achieve basic movements that are essential for letter stroke and daily object handling (Barros, Conejo, deDiego Cottinelli, and García, 2014, p. 1). The primary aim of this discipline is to educate and proofread primary movements used in writing. These movements are part of a motor-perceptive process compilation that involves a succession of movements intended to develop fine motor accuracy, coordination, speed, distension and control. A cyclical process must be followed starting from a very simple level and continuing to a more complex levels through exercises that allow greater control at the elbow, forearm, wrist, hand and finger. Psychomotor re-education can be defined as specialized training to reestablish the connection between cognitive functions that lead to specific physical movements. (Espinoza, 2012, p. 7; Camacho, 2012, p. 2; Dejean de la Batie, 2016, p. 56)

The purpose of this study was twofold. First, we aimed to establish if Graphomotricity, as a physiotherapy addition, is effective for fine motor skill recovery after radial nerve traumatic injury. Second, we sought to understand this therapy's efficacy in adults with a fine motor skill disturbance by following the development line to tack gradual function restoration.

Materials and Methods

From September 2017 to July 2018, a non-randomized clinical trial was conducted at Xoco General Hospital (Hospital General Xoco) involving male and female patients aged 18 -70 years with mid-distal humeral shaft fractures due to automobile accidents, falls or gunshot wounds. Additionally, each patient had clinical diagnosis of radial nerve neuropraxia confirmed with electromyography *(Picture 1)*. They were all treated with neuromodulators and medications that helped regenerate neural tissue.

Picture 1. Hallmark of radial nerve injury. Wrist drop

Patients that were under the age of 18, pregnant or presenting radial nerve axonotmesis were excluded. Patients presenting with central nervous system injury, radial nerve neurotmesis, infection in the injured area, an open wound or radial neuropathy due to systemic diseases or multineuropathic neuromuscular syndromes were eliminated.

Dependent Variable:

The Disabilities of the Arm, Shoulder and Hand (DASH) test was applied to participants at the beginning and at the end of their treatment in order to measure physical function changes of the upper limb. Goniometry *(Picture 2)* and dynamometry (TRAILITE ® TL-LSC100) were used to measure range of motion and obtain quantitative data on the strength of the muscles in the wrist and fingers.

Picture 2. Wrist extension goniometry

Independent Variable:

Conventional physiotherapeutic intervention was represented using a TENS electrostimulation. The TENS unit was applied longitudinally along the radial nerve for 15 minutes with symmetrical biphasic pulses at a frequency of 120 Hz and pulse width of 100 μs. Manual therapy consisting of slow and sustained arthrokinematic mobilization of the hand and wrist joint, along with laser therapy at 100% with pulse frequencies between 2.5 Hz and 2000 Hz for no more than 4 minutes. Active mobilizations of the shoulder and elbow combined with passive mobilizations of the wrist and fingers as the patients' tolerance allowed were utilized. Isometric exercises for the shoulder and elbow muscles were also used to avoid hypotrophy and joint stiffness. A progression of therapy was followed for each patient. It began with gradual active, then active assisted mobilizations of the wrist and hand, followed by isometric then isotonic strengthening of wrist extensor muscles. Finally, neurodynamics and myofascial trigger points release was applied to the muscles of the neck, shoulder, arm and forearm for approximately 12-15 minutes.

Experimental physiotherapeutic intervention involved applying conventional therapy plus graphomotricity exercises. These exercises consisted of stimulating the pincer grasp as well as encouraging use of the entire hand. The various materials used include:

- Shaving cream. The cream was placed on a flat surface so that the patient could begin to spread it, first using their whole hand and then with each finger. Pressure was increased as the patient's strength and confidence improved. This sensorimotor technique helped the patient progress from the gross grasp to the pincer grasp *(Picture 3)*.

Picture 3. Shaving cream to stimulate fine motor skills

- Soft plasticine for strengthening the fingers.
- Markers were used to draw wide strokes with thick markers on flip charts. This involved the use of the whole arm from the proximal joint.
- Thick crayons and markers were used for drawing on a mirror (*Picture 4*, or on paper). Tools were gradually decreased in circumference until the patient could use a pen or pencil.

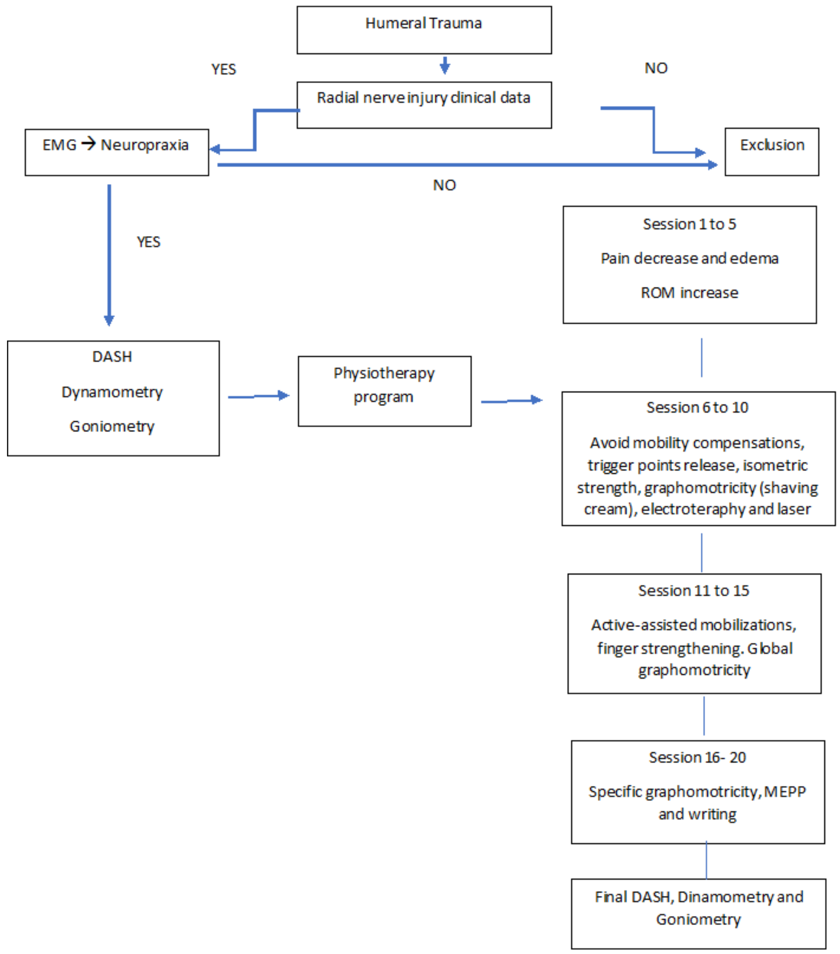
Picture 4. Mirror grasps

- Sheets of paper were torn into shreds, then crushed into a ball by squeezing the fingers together.
- A pincer grasp and grasp stimulation cloth (Mantel para Estimulación de Prensión y Pinza fina, or MEPP in Spanish) *(Picture 5)*. The MEPP is a large piece of fabric with different sections for pincer grasp training and stimulation. The fabric is used to help train activities of daily life. The MEPP has a zipper, large and small buttons with their respective holes and a pressure button that simulate the use of pants and jackets. Additionally, it has a shoelace that needs to be inserted through small holes around the cloth and two hooks similar to the ones on female undergarments.

Picture 5. Grasp stimulation cloth (MEPP)

- A small bouncing ball was used to increase segmental motor control and exercise the shoulder and the elbow for postural compensation.

Therapy sessions lasted between 45 and 60 minutes, twice a week for 10 weeks *(Chart)*.



Statistical analysis

Descriptive statistics: The quantitative variables were summarized using measures of central tendency and dispersion according to their distribution, average and standard deviation. If their distribution was normal, and their median and interquartile ranges if it was distribution-free. Absolute and relative frequencies were used for qualitative variables.

Inferential statistics: The Wilcoxon test was used to compare the initial and final evaluations of functionality, strength and range of motion.

Ethical aspects: The project was submitted to and authorized by the Xoco General Hospital ethics committee.

Results

Twelve distal humeral fracture and radial nerve damage patients (mean 31 years old) (IQR 23.5-51.5) were evaluated. The most frequent injury mechanism was falling (6), followed by automobile accidents (4) and gunshot wounds (2). All twelve patients' clinical data showed radial nerve injury, verified by an electromyography, and neuropraxia. The most commonly affected limb was the right arm (58.30%). The majority of patients were right-handed *(Table 1)*.

Table 1. Sample characteristics (n= 12)

Variable	n o X	(DE) o %
BMI, mean, SD	24	(2.7)
Gender		
Male	7	58.30%
Female	5	41.70%
Injured Limb		
Right	7	58.30%
Left	5	41.70%
Injury Mechanism		
Fall	6	50%
MVA	4	33.30%
PAF	2	16.70%
Laterality		
Right handed	10	83.30%
Left handed	2	16.70%

The results of goniometry indicate a significant ($p < 0.001$) increase in average range of motion from 5.67 to 71.50. Additionally, the results of dynamometry present a significant ($p < 0.001$) increase in average strength from 4.40 to 39.30. The DASH test, designed to measure physical function and symptoms of patients with upper limb musculoskeletal alterations, was performed before initial therapeutic intervention and repeated after the conclusion of 15 physical therapy sessions. Results indicate significant ($p < 0.001$) improvement in patient functionality. There was a significant decrease in average functional limitation between the initial (72.67) and final DASH (17.95) *(Table 2)*.

All patients reported satisfaction with the functionality of their affected hand after the interventions.

Table 2. Initial and final mobility, strength and functionality comparison.

	Initial		Final		
	Mean	**SD**	**Mean**	**SD**	**P Value**
D (Lb)	4.40	5.85	39.30	10.30	0.001
G (o)	5.67	5.09	71.50	10.09	0.001
DASH	72.67	8.35	17.95	8.15	0.001

(D (Lb) = Dynamometry, G (°)= Goniometry, DASH = Disabilities of the Arm, Shoulder and Hand).

Discussion

The specialized therapeutic techniques used in this study significantly improved in fine motor skills in the patient's injured hands. Moreover, a significant increase in range of motion and strength, as measured by goniometry and dynamometry respectively, was noted.

From the possible etiologic factors to disturb radial nerve function, the three of the most commonly reported in our patients were falls, followed by automobile accidents, and gunshot wounds. This aligns with previous research in Castillo et al, 2014. Male gender was most prevalent our patient population as reported in similar research in Masson, 2012 and Castillo et al., 2014.

Motor progress follows nervous system development and is guided by sensation. We understand the world around us using postural reactions, grasp, locomotion, and fine motor skills.

In motor development, children start with global mobility then acquire hand, and upper torso control. Their movements become more coordinated, agile and harmonious over time. Pre-primary aged children's progressive neuromuscular maturity is the basis for their dexterity increase in psychomotor activities. Children learn first to manipulate larger objects and, with time, start to utilize smaller items (Campo, Jiménez, Maestre, Paredes, 2011, p. 79).

Radial nerve clinical data includes wrist drop, grip strength decrease, thumb extension and abduction loss. These losses decrease fine motor skills needed to complete activities of daily life such as picking up an object, writing, and buttoning a shirt. (Cañellas Trobat, Jato, Cañellas Ruesga., 2012, p. 30) Graphomotricity allows a global approach with therapeutic and ludic accompaniment. These techniques are based on corporeal experience which allow for motor-perceptive functions and development of new abilities.

The novelty of our study lies in the use of graphomotricity with adults that have radial nerve injury. Previous research studies graphomotricity for children's writing process in accordance with their development. In case of radial nerve injuries, this same technique can be used because the principal aim is to change from a precarious to a more developed grip.

A potential limitation for the study was the low sample size for evaluation. Additionally, some patients had difficult attending therapy because of distance or transportation. Patient's laterality also limited the study because most of the tools used were designed for right-handed individuals. Finally, non-dominant hand injuries showed increased difficulty in performing and coordinating some activities.

More research and studies are needed to confirm the positive benefit of adding this therapeutic technique. Future studies should consider including a control group to determine the impact of Graphomotricity and decrease the chance for bias. Finally, a future study should include a larger sample size. Nevertheless, the data obtained from this study indicate that graphomotricity is not exclusive for children. This study suggests, through the use of a variety of therapeutic techniques, skills that have been lost or disturbed in adulthood can be acquired once again.

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