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FUNCTIONAL ABILITY DEVELOPMENT
OF THE UPPER EXTREMITY
WITH MIRROR THERAPY FOR STROKE PATIENTS
WITH HEMIPLEGIA
A LITERATURE REVIEW

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The purpose of this thesis was to find out the evidence based effects of mirror therapy for stroke patients with hemiplegia regarding to their functional ability of the upper extremity as a part of physiotherapy rehabilitation.

The search for free full access articles was done by using these online databases; PubMed, Cochrane Library and ResearchGate. The aim was to find recent articles since 2009 in which six relevant studies were found and were rated using the PEDro scale.

Mirror therapy was found to be a simple non pharmacological and cost effective method to improve the functional ability for a stroke patient suffering from hemiplegia of the upper extremity. It should be known that only six studies were included in this review due to the specific research strategy and further research is needed to determine the usefulness and effectiveness of mirror therapy regarding to improving functional ability for motor impairment post-stroke. Type of exercises and the protocol used in mirror therapy should be established and the expected outcome of the intervention.

1 INTRODUCTION

Upper extremity (UE) disability is one of the most common neurological consequences after a stroke. It includes limitations in motor ability and restriction in functional use of the affected UE that follow up with a weakening or paralysis of the muscles, abnormal muscle tone, associated reaction, coordination disorder and problems with the musculoskeletal system. (Woodson, 2008.) These dysfunctions can negatively impact the performance of daily living activities which can substantially reduce one's quality of life as their functional dependence is reduced (Gillen, 2012, 844–880).

There are many different ways as to how physiotherapy is used to rehabilitate individuals with hemiplegia, such as; a wide range of motion exercises, flexibility training, electrical stimulation, modified constraint-induced therapy, cortical stimulation and motor imagery where it relates to mirror therapy (MT). For the past two decades, MT has been studied and practiced which gave its recognition for its abilities to activate neurons in the brain to its maximum motor function potential. This is a therapeutic intervention that uses visual feedback to enhance neuroplastic changes and trigger motivation through these feedbacks during training. (Ji, et al., 2014, 497-9.)

The precise protocol for stroke rehabilitation for hemiplegia does not vary substantially as it is worldwide knowledge that usage of the weakened body part is essential for motor recovery. However, the various treatments used may vary within different parts of the world, depending on its facilities and if the knowledge is up to date with its most recent research based treatments. The general exercises used in treatments include movements that will promote mobility and strengthen the hemiplegic limb which will therefore reduce impairment as much as possible and reach a functional goal. The use of MT is not widely used as a common form of treatment as its level of effectiveness is questioned due to the lack of evidence. (Deconinck, et al., 2015, 349-61.)

2 BRAIN

2.1 Structure and function of the brain

The brain is the birthplace of the qualities that define humanity. It is a remarkable organ that withholds mysteries which scientists are still unable to explain. Scientists are unable to acknowledge what the brain is fully capable of - which alone, is outstanding to think that this powerful body part is present in each of us all. The whole world is how one perceives the environment, living through the nervous system. (Blažević, 2015.) The brain is the most complex organ in the human anatomy. It wields the individual's' intelligence, interprets senses and is believed to be the source production of conscious and unconscious body movement and behaviour. (Cherry, 2019.)

The brain is a network containing around one hundred billion neurons and trillions of interneuron connections. Unique experiences construct the formation of the adult brain by creating new neural connections, and depending on which neurons get stimulated, bring out the specific actions one does with their attached emotions. As more similar experiences are commenced in a person, certain connections become stronger and eventually are more efficient working together. (Tortora & Derrickson, 2011, 527-556.) This is how skills can be learnt, enhanced and then perfected in many different ways, whether it is to shoot a three-pointer in basketball or know how to dice onions which all required motor function. With a sudden change of circumstances, skills that were gradually produced over years of natural development and training can be eradicated. One reason for this to happen is strictly due to the fact that the area of the brain that contained the neural connections responsible for these specific abilities had had a lack of nutrition needed for its survival. One incident that can be the cause for this to happen is a stroke, where there is an obstruction of blood supply to the most precious organ in the human body, the brain. Like all living beings, a form of nutrition is needed so that energy can be created for surviving. A possible interruption or halt to the means of energy support can sometimes have no or a very minute consequence in some situations. However, in the circumstance for this to occur to the very core of our survival, the slightest suspension can give devastating effects. (Blažević, 2015.)

The brain can be divided into different parts according to its particular function. However, they all work together to form all the possible qualities of life that we are aware of today. The forebrain is the most developed and largest part of the human brain which consists of the cerebrum and the compositions within it. It holds the ability to store memories, to think, plan and imagine - along with other cognitive activities. The hindbrain includes the upper most part of the spinal cord which is part of the brain stem in which the tissue is named the cerebellum. This part of the brain controls the body's vital functions such as heart rate and respiration and the body's coordinated movements, such as playing a musical instrument. The midbrain is located in the uppermost part of the brain stem which controls some reflex actions and involves the process of controlled eye movement and voluntary actions. (Hines, 2018.)

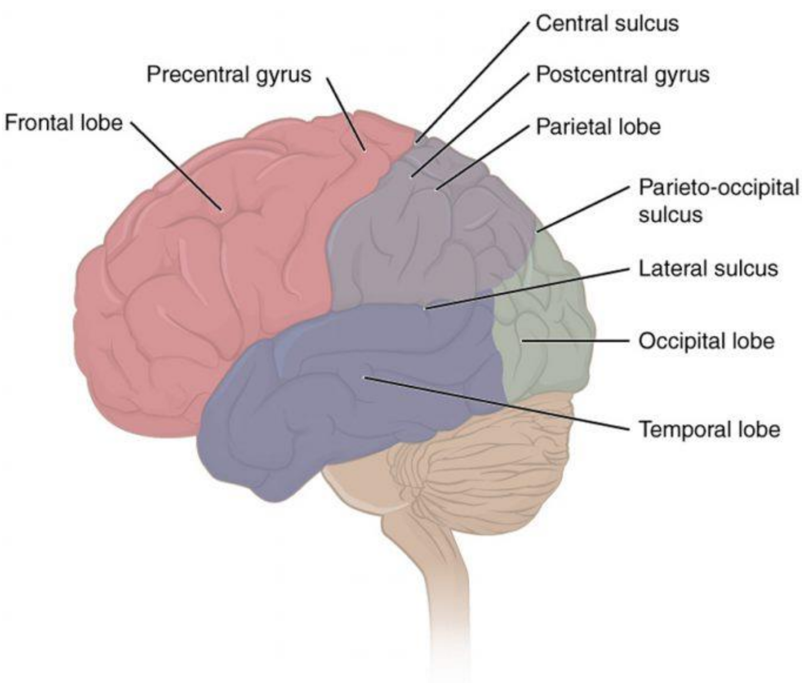

Figure 1. Lobes of the cerebral cortex. (Biga, et al., 2018)

Each cerebral hemisphere has specific lobes in which each specialises in specific functions. The location of these lobes in the brain can be seen in the above diagram in Figure 1. As this thesis is specifically concerned towards the functional ability of the UE, it will be focusing mostly on the specific parts of the brain that affects mostly motor and sensory ability. The rearmost part of the frontal lobe is where controlled voluntary movement is produced and is known as a motor area of the brain. There is the primary and secondary motor cortex. The primary motor cortex is located along the precentral gyrus which produces the neural impulses that control movement performance. The neural impulses are signalled from the primary motor area and crosses through the body's midline to its specific skeletal muscle. The secondary motor areas are involved in the planning of motor output. (Schwerin, 2013.) The primary somatosensory cortex is responsible for processing somatic sensations and is located in the ridge cortex in the parietal lobe called the postcentral gyrus. It is located just posterior to a fissure that runs down the side of the cerebral cortex named the central sulcus. Somatic sensations are responsible for proprioception, nociception, temperature and touch which arise from numerous receptors positioned throughout the body. The feedback from these sensations is sent directly to the primary somatosensory cortex through the thalamus. Table 1. below states the specialised functions of each different areas and lobes of the brain. (Purves, et al, 2008.)

Table 1. Areas of the brain and their functions (Wache, 2008; Tonya, 2018)

Areas of the brain	**Function**
Lateral ventricle hippocampus / internal frontal lobe areas	Short-term memory processing Limbic system (emotions and motivation)
Thalamas is part of the diencephalon	Integrates neurons for short-term memory
Hyothalamus	Concerned autonomic functions Limbic system
Frontal lobe	Primary olfactory area Broca's speech and writing motor area Personality, behaviour, emotions Body movement (motor strip) Intelligence, concentration, self-awareness
Parietal lobe / along lateral sulcus	Gustatory area Interprets language, words Sense of touch, pain, temperature (sensory strip)

	Interprets signals from vision, hearing, motor, sensory and memory Spatial and visual perception
Temporal lobe	Wernicke’s speech comprehension are; Primary auditory / hearing association area. Sequencing and organization Memory
Occipital lobes	Visual association area / perceptions

The cerebrum is the most visible part of the brain where it can be split into two hemispheres due to the deep fissure present in the midline named the longitudinal fissure. Even though the cerebrum may be observed as split halves and may look identical, the two hemispheres have different functions in which they are in constant communication with each other from a thick tract of nerve fibres called the commissural tract that lie deep beneath the fissure. Nearly all signals that travel from the brain to the body and back again crossover on the exiting of the brain. This simply means that the right hemisphere is in control of the left side of body movements and vice-versa. The anatomy of the brain contains different locations where specific parts have their identifications at which each has its own function. (Tortora & Derrickson, 2011, 527-556.)

The cortical homunculus represents the anatomical divisions of the primary motor cortex and the primary somatosensory cortex. It is responsible for the sensations that arise from touch, proprioception, nociception and temperature. Therefore, embodies how an individual may perceive their own body within the brain and the distribution of neurons in order to create this perception. However, it is important to recognise that between body parts and its representation it has in the cortical homunculus is not proportional. This means that certain areas, such as the hand, occupy a disproportionately large part of the cortex due to the importance of fine motor skills, coordinated movements of the fingers and the ability of the fingers to feel the environment. (This is essential knowledge when it comes to the discussion of the severity to a stroke patient’s hemiplegia.) Thinking about this in the necessary sensitivity needed to read Braille. This can be compared to that of the entire back, where it is substantially bigger than the hand however does not require more circuitry and density of nerve endings than that of the fingertips. Therefore, there is an arrangement that is referred to as somatotopic, and the full body is represented in this way in each of the four divisions of the somatosensory cortex. Korbinian Brodmann, a German neuroscientist, identified 52 distinct regions of the brain according to differences in cellular composition and is referred to as Brodmann's areas. Brodmann's area 3a and 3b, 2 and 1 are divisions and subdivisions of the primary somatosensory. These numbers indicate the order in which the somatosensory cortex was examined and not to its importance. Area 3 is generally considered the primary area of the somatosensory cortex. Most of the somatosensory input is received by area 3 where the initial processing of this information occurs comes directly from the thalamus. 3a is responsible for the processing of information regarding to proprioception whist 3b is specifically concerned with basic processing of touch sensations. (Purves, et al., 2008.)

There is a dense neural connection between area 3b and areas 1 and 2 which allows for the information that is received from 3b to be sent to areas 1 and 2 for more complex processing. Area 1 shows responsibility for recognition of texture whilst area 2 appears to be responsible perceiving shape and size as well as proprioception. The arrangement for these four areas of the primary somatosensory cortex is made to be able to receive information from a specific part of the body. The whole body is represented this way in each of the four divisions of the somatosensory cortex in which this whole arrangement is referred to as somatotopic. Parts of the body that require more circuitry, due to their higher sensitivity than other parts, will occupy a larger amount of space in the somatosensory cortex. Any damage to these areas will most likely result in negative effect towards that specific part of the body where the area is responsible for. Therefore, if there was damage caused by a stroke in the somatosensory cortex in the left hemisphere in the area where it is devoted to the UE. This would most likely affect the sensations of the right UE, to an extent where it depends on the level of damage that occurred in that specific area of the brain. (Purves, et al., 2008.)

2.2 Mirror neurons

The primary functional unit for the brain and the whole nervous system is called a neuron. The neuron allows the impulse of electrical signals to travel which aids in the process of human body to feel sensations and emotions, create movement and thoughts and store memories. A neuron contains a cell body which holds the nucleus that provides the molecules needed for the cell to survive and function. Like branches of a tree, neurons contain dendrites that extend from the cell body and have the function of receiving messages from other neurons. The signal is then continued through the cell body and may exit out from the axon to another neuron, or muscle or organ cell. Neurons are usually aided by supporting cells such as myelin, made from fatty molecules, which acts as an insulating sheath that is wrapped around the axon to help increase the speed and length of the electrical conduction rate. A synapse is the chemical or electric meeting points between brain cells where the signal is passed from one neuron to another. When the electrical impulse reaches to the end of the axon, chemicals called neurotransmitters are released from sacs into the synapse area. Receptors of the receiving neuron attach to these neurotransmitters that have travelled from the synapse, which causes a change to the properties of that cell and allows the electrical signal to continue into that receiving neuron. (Lago-Rodríguez, et al., 2014, 82-103.)

Based on the characteristics of a neuron, the separation of the brain tissue into grey and white matter can be explained. Pinkish-grey in colour, grey matter contains neural cell bodies, axon terminal, dendrites and nerve synapses. This tissue is plentiful in the cerebrum, cerebellum and brain stem and forms the butterfly-shape in the central spinal cord. White matter of the brain and spinal cord is constructed with bundles of axons that are wrapped with myelin which is the reason to the white colour of the tissue. Conduction and processing of nerve signals is the main role of the white matter in the spinal cord. If damage is present in this tissue, it can affect motor or sensory abilities. (Villines, 2015.)

Mirror neurons first became noticed in a study with macaque monkeys made guided by Giacomo Rizzolatti and a team of neuroscientists in 1992. They have shown that observation and performance of a specific action fires an electrical pulse, or action potential which produces similar impulses to each other. These were found using electrodes inserted to the brain and has shown for the first time the presence of mirror neuron responding to observing actions similar to how one would perform the action themselves. Below at Figure 2. illustrates a graph showing the action potentials what would have been measured with an electrode used by the researchers. (JohnMark, 2016.)

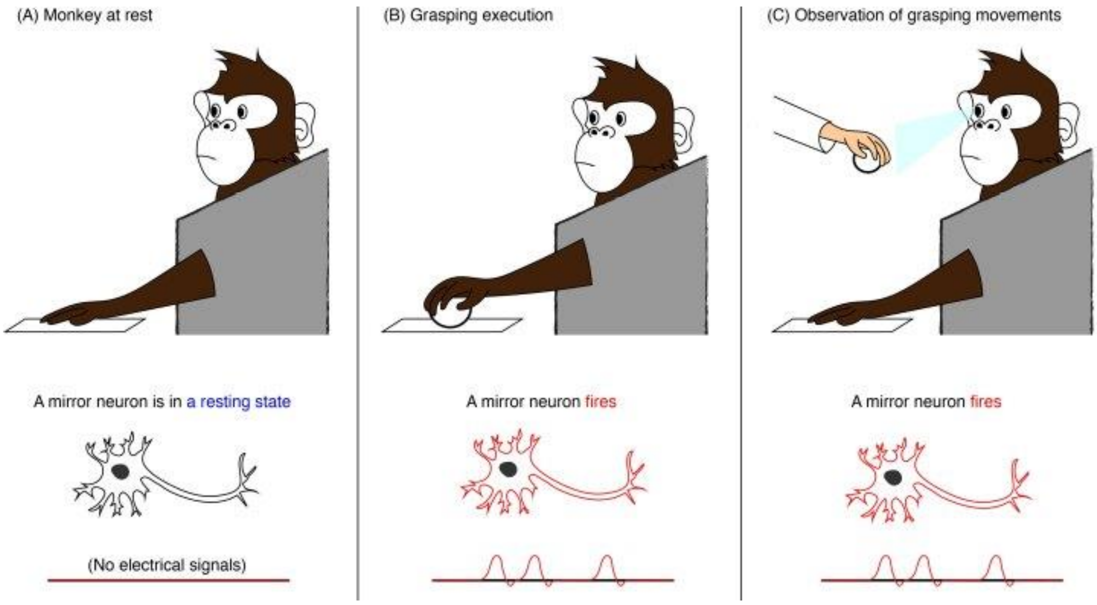

Figure 2. A illustration comparing how mirror neurons are activated at rest, performing an action and observation of the same action. (JohnMark, 2016).

Mirror neurons are neurons that becomes stimulated when an action is performed or when the same action is being observed from another being; hence the name "mirror" neuron. Movement is created due to the signalling of the CNS to the motor neurons to initiate activation of the necessary muscles while mirror neurons are specifically recognised when they are activated when movement is seen from the individual. This knowledge is fundamental when discussing MT as the mirror creates the appearance that the affected limb is moving, in which the brain processes that visual feedback due to the firing of mirror neurons. The illusion is created with the reflection of the healthy limb and the brain perceives it as the affected arm. This comes to the consensus that this signalling in the brain can improve mobility. As this phenomenon revolves around neuroplasticity, some of the success can be of help from mirror neurons. However, at this moment their level of assistance is still unable to be fully measurable. (Ramachandran & Altschul, 2009, 1693–1710.)

The discovery of mirror neurons has made a large impact on research studies for neuroscience due to its observational motor learning ability. Mirror neurons are a variety of visuospatial neurons which demonstrate the importance of human social interaction as they respond to the actions seen by ourselves made by other individuals. Moreover, these cells fire in the same way as if the actions were being performed personally. Mirror neurons are also found to be responsible for multiple other advanced human behaviour and thought processes. (Acharya & Shukla, 2012, 118–124.)

Mirror neurons are being noticed for neuro-rehabilitation potential as their active presence in the brain from visual information provokes signalling in the same location as if the individual were performing the action themselves. Therefore, these visio-motor neurons show the potential of producing motor patterns before even attempting the action physically. Studies have shown that action perception and motor execution can be improved just from observational motor learning. Therefore, it may be said that the perception of an action being performed can positively interact with the possible execution of a physical action due to a shared common neural mechanism. This knowledge is promising to be able to play a major role for further development in neurological rehabilitation. (Lago-Rodríguez, et al., 2014, 82-103.)

Complex movements are most often able to be performed by first observing the actual motion before practicing it, which is unmistakable at childhood years. According to Vida Demarin et. al (2014), the mirror neuron system are located in the cortical ventral premotor cortex and base of parietal. These areas have potential to be beneficial neuroanatomical target areas for rehabilitation exercises. The objective is to attain their activation through any connected healthy part of the cortical network. The mirror neuron system will activate differently in every person, depending on individual’s level of practice of specific movement. An explanation for producing such stimulation of a larger network area and reconnection of large number of synapses with an example would be if a patient who played the piano and danced salsa prior to stroke. A presence of stronger activation of mirror neurons would occur through this observation of these more meaningful activities. (Demarin, et al., 2014, 209-211.)

3 NERVOUS SYSTEM OF THE UPPER EXTREMITY

Nerve impulses are generated from the primary motor cortex, in which the signal is conducted through the corticospinal tract through the white matter in the spine. The impulse is synapsed on interneurons and motor neurons in the spinal cords vertical horn which have its ventral roots to innervate their specialised muscle fibres. (Schwerin, 2013.) The brachial plexus is the main nerve supply for the upper extremities which can be best described as a complex intercommunicating network of nerves. It all starts with the nerve roots leaving from the spine to create the superior, middle and inferior trunks. The superior trunk is responsible for the innervation of nerves towards the suprascapular and subclavicle. After some further intercommunication between the three trunks, they soon form the lateral, posterior and medial cords. The lateral cord contains a nerve that innervates the lateral pectoral. The posterior cord innervates the upper subscapular, thoracodorsal and lower subscapular. The medial cord innervates the medial pectoral, medial cutaneous nerve of arm and medial cutaneous nerve of forearm. After further intercommunication between the cords, the final main five nerves are formed for the UE: axillary, musculocutaneous, radial, medial and ulnar nerve. (Agur & Dalley, 2013, 488-494.) Below at Table 2 and 3. states the origin, course of each nerve and to which part of the UE it is responsible for in terms of sensory and motor potential. It defines how motor and sensory output and input connects from the whole UE to the CNS. (Watson, 2011.)

Table 2. Origin, course and sensory and motor role of musculocutaneous, axillary and radial nerve (Watson, 2011)

	Musculocutaneous	**Axillary**	**Radial**
Origin	C5/C6/C7 Anterior portion of superior and middle trunks into lateral cord	C5/C6 Posterior portion of superior trunk into posterior cord	C5/C6/C7/C8/T1 Posterior portion of superior, middle and inferior trunks into posterior cord

Course	Through the anterior part of arm beneath the biceps muscle. Becomes *lateral cutaneous nerve o forearm*	Passes beneath shoulder joint into posterior part of arm and wraps around surgical neck of humerus	Winds around spiral groove of humerus, divides into two branches in the forearm *superficial* and *deep/posterior interosseous*
Supplies	Sensory – Lateral forearm Motor – *Anterior part of arm* a. Biceps brachii b. Brachialis c. Coracobrachialis	Sensory – "Sergeants patch" over lower deltoid Motor – • Deltoid • Teres minor	Sensory – Lower posterior arm, posterior forearm, lateral 2/3 dorsum of hand, proximal dorsal aspect of lateral 3 ½ fingers Motor – *Posterior part of arm* • Triceps brachii *Posterior part of forearm* • Wrist extensors • Finger extensors • Brachioradialis • Supinator

Table 3. Origin, course and sensory and motor role of median and ulnar nerve (Watson, 2011)

	Median	**Ulnar**
Origin	C5/C6/C7/C8/T1 Lateral root from anterior portion of superior and middle trunks into lateral cord Medial root from anterior portion of inferior trunk into medial cord	C8/T1 Anterior portion of inferior trunk into medial cord
Course	Follows with brachial artery, divides into three branches in the forearm *anterior interosseous, deep superficial/palmar cutaneous*	Follows with brachial artery, passes behind medial epicondyle into forearm, then enters anterior part along with the ulnar artery to enter the palm of hand via Guyon's canal

Supplies	Sensory – Thenar eminence, lateral 2/3 palm of hand, palmar aspect lateral 3 ½ fingers distal dorsal aspect of lateral 3 ½ fingers Motor – all muscles of *anterior part of forearm* EXCEPT flexor carpi ulnaris and two parts of flexor digitorum profundus: • Wrist flexors • Finger flexors • Pronator teres + quadratus	Sensory – Hypothenar eminence, medial 1/3 palm of hand, palmar aspect medial 1 ½ fingers, whole dorsal aspect of medial 1 ½ fingers, medial 1/3 dorsum of hand Motor – Two muscles of *anterior part of forearm*: • Flexor carpi ulnaris • Two parts of flexor digitorum profundus

4 STROKE

4.1 Definition of stroke

Defined by Gursimran S. Kochhar, et al., (2013) a stroke is an interruption of cerebral blood supply to a region of the brain, usually because a blood vessel bursts or is blocked by a clot. This vascular injury disallows the blood flow to a certain area of the brain which causes brain anoxia and damage to the tissue as there is a fatal reduction of blood supply. (Kochhar, et al., 2013, 33-46.)

The effects of a stroke depend on the area of the brain that is blood-deprived and to what extent of extremity is the destruction of the brain tissue. The immediate symptoms that are common of a stroke are sudden weakness or numbness of the face, arm or leg that are often on one lateral side of the body. Mentioning a few other more correlating symptoms: confusion, difficulty speaking or understanding speech, difficulty seeing with one or both eyes, difficulty with walking, dizziness, loss of balance or coordination, severe headache and fainting or unconsciousness. (Kochhar Gursimran, et al., 2013, 33-46.)

Hypertension is the largest factor of why stroke occurs in patients. Other medical factors are hyperlipidaemia, atrial fibrillation, diabetes, history of transient ischemic attack and obstructive sleep apnea. Lifestyle risk factors are tobacco smoking, alcohol use, diet and physical inactivity. (Kochhar, et al., 2013, 33-46.) Factors that are non-modifiable are; age, male sex, black race, previous myocardial infarction and a family history of stroke. (Goldstein, et al., 2011).

4.2 Clot strokes

Transient ischemic attack, also known as a mini-stroke or as a warning stroke, is a temporary block of blood flow towards the brain caused by a blood clot which causes symptoms of a stroke for a short period of time. An ischemic stroke happens when an artery becomes blocked from a blood clot which usually occurs due to atherosclerosis. This is a build-up of fatty deposits that developed in size from the inner lining of a blood vessel away from the brain and eventually some or most of the mass detaches and clogs an artery that bring blood to the brain. If the artery is blocked for more than a few minutes, brain cells will due to a lack of needed resources. This leads to the essential knowledge that quick actions are essential for a stroke victim and they need treatment as soon as possible. Thrombotic strokes are caused similarly to an ischemic stroke; however instead of the clot being formed in a blood vessel away from the brain, the clot is formed in a vessel inside the brain. (Gomes & Wachsman, 2013, 15-31.)

4.3 Bleeding stroke

Ruptures or breaking of the blood vessel in the brain causes leaking of blood in the surrounding tissues which applies too much pressure on the brain, which damages its cells. This classifies as a haemorrhagic stroke. (Gomes & Wachsman, 2013, 15-31.)

Aneurysm is a type of Haemorrhagic stroke which causes an area to expand in a weakened blood vessel and occasionally can rupture. Ateriovenous malformation is where abnormal formed blooded where they are most likely to rupture and cause bleeding. Intracerebral haemorrhage is the most common type of haemorrhage stroke, this is where an artery bursts in the brain and causes bleeding surrounding tissue. Subarachnoid haemorrhage is the less common type of haemorrhagic stroke, refers to the pressure build-up of blood between the thin tissues that surrounds the brain and the brain itself. (Gomes & Wachsman, 2013, 15-31.)

4.4 Anterior and posterior brain region stroke differentiation

Looking at the anterior blood circulation there are the; ophthalmic, medial carotid (MCA) and anterior carotid arteries (ACA). The ophthalmic artery affects vision of an individual. After a stroke in this artery, blindness can occur and it may be called “transient blindness” which is also clinically called an amaurosis fugax. The MCA supplies blood to the lateral frontal lobes, temporal lobes and lateral anterior parietal lobes. The specific functions from these parts control the upper body motor sensory cortex (mostly for the face and UE) and language in the Broca’s and Wernicke's area. Finally, from the anterior circulation of the brain leads a connection to the lower body, pelvic floor musculature and sensory integration with the medial and anterior frontal lobes and medial parietal lobes. These are supplied by the more medial ACA. (Hines, 2018; Channing, 2019.)

The circulation of blood on the posterior region of the brain includes; the basilar artery, the posterior carotid artery (PCA) and the posterior inferior cerebellar artery (PICA). A stroke occurrence for the basilar artery can be tragic as this result in the patient only being able to move their eyes and be conscious and aware of the surroundings. PCA supplies blood to the occipital, posterior temporal, posterior parietal lobes and midbrain and various cranial nerve ganglia (III, VII, X, XII). The specific functions from these parts of the brain control vision, balance, sensory integration and cranial nerve function. The posterior inferior cerebellum and posterior lateral medulla is supplied by the PICA. This controls the facial sensation and pain sensation from the body. Below at Figure 3. presents the major arteries of the brain. (Hines, 2018; Channing, 2019.)

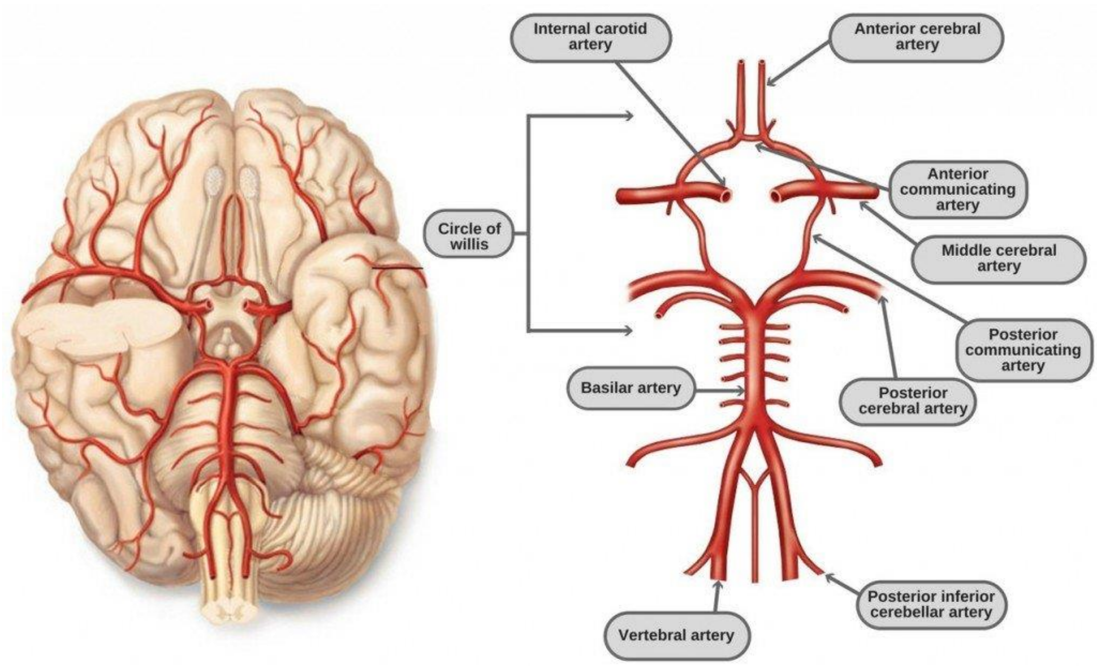

Figure 3. Anatomy of the major arteries of the brain. (Ashish, 2017).

4.5 Cortical and subcortical strokes differentiations

The lobes that may be affected in a cortical stroke of the cerebral cortex are the frontal, parietal, temporal and occipital lobes. Beneath the cortex, stroke may occur subcortically, in the internal capsule, thalamus, basal ganglia, brainstem and cerebellum. Lesions occurred in the cortical area may present a higher loss of order sensory function that are different from subcortical sensory impairment. These impairments include contralateral agraphesthesia (parietal lobe), astereognosia (parietal lobe), visual disturbances and abnormalities (occipital lobe), and gaze preferences. All of these sensory deficits are dependent on the lobe that was affected by the stroke. Subcortical strokes can cause extrasocular movement impairments, diplopia, dysphagia, dysarthria, nystagmus. Specifically for the cerebellum, symptoms of with nausea, vomiting, vertigo, imbalance may be present and nystagmus, ataxia and tremor. (Tocco, 2011.)

Differentiation of whether a stroke has occurred in the cortical or subcortical region can be assisted by assessing the presence of motor and sensory impairments. The homunculus assists the recognition of characteristics of cortical motor or sensory deficits. Using an example to explain, a left MCA stroke will most commonly cause motor deficit mostly involving the right face and arm. Whereas, a left ACA stroke will paramountly affect the right leg more than face and arm with possible distal extremity experiencing focal weakness. However, an equal level of impairment may occur for the face, arm and leg in a subcortical stroke. This is due to the contiguity of the corticospinal tract fibres as they run through the subcortical structures. If a cortical stroke causes primary sensation impairment in which it is distributed based on the topographical representation of the homunculus. In contrast, a small subcortical thalamic infarct has the ability to impair the entire hemibody, whilst it would be quite uncommon for a cortical stroke to affect the whole contralateral side of the body. (Tocco, 2011.)

4.6 Acute medical and mobilising treatment

Emergency management for a stroke patient is to recognise the type of stroke the patient has. To differentiate between ischemic or haemorrhagic, a non-contrast computer tomography is needed. Magnetic Resonance Imaging (MRI) is more accurate however, it is rarely performed as it takes more time. Laboratory routines including; glucose, INRs and EKG should also be performed. Until then, the patient should be supplied adequate tissue oxygenation through airway management. Blood pressure should be controlled for the first 24-28 hours usually with labetalol immediately if the systolic blood pressure amounts to over 220 mmHg. Glucose levels must be normalised as negative outcomes can occur with both hypoglycaemia and hyperglycaemia. Fever must be managed with antipyretic medications to keep body temperature below 37.7 degrees Celsius. (Bansal, et al., 2013.)

These treatments are specifically helpful for ischemic strokes and not for haemorrhages. Administration of a clot-dissolving drug is crucial to lower the risks of damage to the brain. A drug named tissue plasminogen activator (t-PA) alteplase, is a protein involved in the breakdown of blood clots and is given intravenously. t-PA is an enzyme known as serine proteases or serine endopeptidases that divide peptide bonds in proteins that serine serves as the nucleophilic amino acid at the active site. Serine proteases are found on endothelial cells of the blood vessels. The enzyme t-PA, catalyses the change of plasminogen to plasmin which is the important as it is responsible for clot breakdown. This medical treatment for strokes is known as thrombolysis. Studies have shown that administering this drug three hours post first symptoms of stroke, is crucial for the survival of the individual regarding their own life of their brain cells. (Donnan, et al., 2008.)

As for very early mobilisation (VEM) treatment, a systematic review made by Langhorne P et al. (2018) included nine trials of 2958 participants. This review stated that there is not enough sufficient evidence proving that mobilisation within the 24 hour time period post-stroke improves recovery comparing to more delayed mobilisation. (Langhorne, et al. 2018.) Xu Tao et al. (2017) had also presented a systematic review with similar conclusions regarding that VEM is not associated with beneficial effects within a 24 or 48 hour time period post stroke. Within the review it states that VEM is defined with intensive out of bed activity that involves sitting, standing and walking no later than 1 or 2 days post-stroke. However, musculoskeletal issues may arise due to extended bed rest, along with cardio-respiratory and immune system dysfunction. Therefore, stroke patients may have slower recovery and may increase mortality and morbidity due to immobilisation (Xu, et al., 2017.) Keating M et al (2012) states that VEM occurs within the first 24 hours after stroke onset whilst ‘early’ mobilisation involves recovery during the first week after onset. As patients have numerous amounts of physiological problems during the very early stages post-stroke, these symptoms may cause risk of safety for the patient to mobilise. Although, when clinical conditions are more stable, early mobilisation within the week can bring great benefits to prevent future complications such as reduction in muscle mass, contractures, pneumonia, deep vein thrombosis, pulmonary embolism, and pressure sores. The first possible positions and movements recommended for early mobilisation are; sitting supported in bed, sitting supported out of bed, transferring with hoist, rolling to sit up, sitting with no support, transferring with feet on the floor and standing. Further research is needed to know the optimum time period to start mobilisation post-stroke. (Keating, et al., 2012, 16-18.)

4.7 Deficiencies that may arise from stroke

Understanding upper limb impairment after stroke is at its highest importance for the physiotherapist when planning therapeutic treatment to restore function. However, to determine a more effective treatment, it may be more individualised than one may have thought. The reason being that when motor recovery proceeds, the essence of impairments may change as they do not remain static, therefore the evolvement of the treatment must keep up to the aim for the impairment contributing to dysfunction. There may also be the presence of more than one impairment at the same time, such as a patient originally obtains weakness to a UE after a stroke and after a few weeks or months develops spasticity. Consequently, multiple impairments may develop over time making it challenging to decide what to treat first. (Raghavan, 2015, 599–610.)

According to Preeti Raghavan (2015), one of the most practical ways to understand how impairments give rise to upper limb dysfunction is to examine them from the perspective of their functional outcome. The three main functional consequences of impairments on upper limb function that Preeti Raghavan states are: learned nonuse, learned bad-use and forgetting as determined by behavioural analysis of tasks. (Raghavan, 2015, 599–610.)

Hemiplegia comes from the two Greek words - “hemi” which mean half, and “plegia” paralysis which leads to the final meaning of the entire one side of the body is in paralysis compared to the other which is not. Stroke can cause hemiplegia, however the type of hemiplegia depends on the precise location of damage on the brain. Weakness or paralysis is the leading cause to dysfunction after stroke. It occurs from the lack of signal transmission from the motor cortex where the impulse for movement is generated to the spinal cord which enforces the movement through the connection of the muscles. Therefore, there is a disturbance for the muscle to contract that result to a lack of movement performance. Sensory loss can also be present with or without motor weakness. Proprioception, tactile information and/or higher-order sensory deficits can be associated post-stroke which can be assessed by two-point discrimination, stereognosis and graphesthesia. Impairments of the UE are an example of a deficit that can occur right after a stroke which may result in nonuse to occur as the individual might abandon the use of that limb entirely due to strength or sensory loss. If the limb is not incorporated into functional activities even though it is possible, this behaviour is learnt and therefore referred to as “learned nonuse”. (Raghavan, 2015, 599–610.)

Weakness and sensory loss can lead to immobility of the limb which can result in stiffness and contracture development, arising motor disorders such as spasticity and abnormal motor synergies. Spasticity is known as a velocity-dependent increase in muscle tone with overly sensitive tendon reaction which causes hyper excitability of the stretch reflex. It is considered that spasticity is a positive development as it shows that there is a process of repair occurring at the nervous system to restore muscle movement and tone. However, continuing reorganisation of the supraspinal descending drive to the spinal cord causes a further reduction of the threshold action reflex, leading to muscle spindles and fascia to be decrease in length. This will develop the spasticity into stretch-sensitive forms such as spastic-co-contraction. Abnormal descending motor commands, also known as abnormal motor synergies, can occur post-stroke which are not in relation to loss of weakness. (Raghavan, 2015, 599–610.)

Ataxia, lack of voluntary coordination of muscle movements, can be present in a stroke patient which is due to a central nervous system (CNS) issue and not to muscle strength loss. This usually occurs by cerebellar lesions, lesion in the basis pontis, corona radiate, thalamus, posterior limb of internal capsule in which most of these regions involve the circulation of the posterior side of the brain. Ataxia can affect trunk control which results to the negative physical performance involving balance and gait. (Choi, 2018, 375-383.)

Arising from left or right brain damage, pusher syndrome is a clinical disorder involving stroke patients to actively push their head or their entire weight away from the non-affected side. Intrinsically, ignoring the hemiplegic side and leading to less intention for rehabilitating to the affected side which leads to further less potential for improvement due to the lack of weight-bearing. Research has shown that patients with severe pushing behaviour show that perception of body posture in connection to gravity is changed. (Karnath & Broetz, 2003, 1119-1125.)

4.8 Assessment of stroke severity

The most substantiated and widely used stroke scale is the National Institutes of Health Stroke Scale (NIHSS). This scale has shown to accurately indicate stroke severity and prognosis in the conditions of clinical practice and clinical trials. The scale is used to objectively quantify the impairment caused by stroke, which consists 11 items, each of which a specific ability scores between a 0 (normal function) and 4 (highest level of impairment). The maximum possible score is 42, with the minimum being a 0. (Racosta, et al., 2014, 178–183.)

5 FUNCTIONAL ABILITY

5.1 Definition of the term functional ability

A persons' functional ability is the current or potential capacity to perform a simple activity or task. Normal functioning of the body involves the combination of biological, psychological and social processes. Quality of life relates to ones' physical and mental health that is also associated with their functional capacity which brings to the importance of it being measureable. Eligibility for rehabilitation care and long-term services and funding uses results from functional ability measures by performing various functional activities. Assessments usually contain the evaluation of activities of daily living (ADLs) and instrumental activities of daily living (IADLs) performances, especially in older people. (Kirch, 2008.) According to Kil-Byung Lim et al. (2016), functional recovery of the UE includes grasping, holding, and manipulating objects, which furthermore demands the employment and complex integration of muscle activation through the shoulder until the fingers. (Kil-Byung, et al., 2016, 629–636.)

5.2 Physical and sensory changes in the upper extremity after stroke

Stroke can affect motor function, therefore affecting factors such as mobility, daily life activities, participation in society and the possibility to returning to professional activities. Quality of life can be negatively affected as a result to these changes. Somatic sensations can be disrupted due to stroke which could lead to a decreased detection of sensory information, impaired motor performance that requires somatosensory information and diminished UE rehabilitation outcomes. Sensation such as touch, proprioception, pain and temperature is essential for ones' safety. Loss of motor function and coordination involving gross and fine motor skills are other main causes for disablement in stroke patients. Gross motor skills involve large muscle groups, allowing for the performance of large movements such as walking and lifting. Whilst fine motor skills involve smaller muscle groups which includes the activities such as writing and picking up small objects. Motor impairment of the UE post-stroke can severely restrict independence as ADLs becomes more time-consuming or rather too difficult of a task to complete. Activities such as dressing, feeding oneself and self and home maintenance can become too difficult. (Hatem Samar, et al., 2016.)

There are many common physiological changes that can occur to the UE after stroke. Specifically relating to the UE, possible paralysis is an issue where it involves the loss of muscle function and sensations. This is strictly due to the damage of the nervous system. Paresis can usually be present in the absence of paralysis, which is the loss of the strength of voluntary movement. Spasticity, coming from the Greek "spasmos" meaning drawing or pulling, occurs due to the obstruction inhibition of motor neurons which causes excessive velocity-dependent muscle contractions also known as cramps or spasms. This results to increased tendon reflex activity and hypertonia. This can negatively affect coordination and muscle movement and therefore make daily living activities more difficult to perform. These spasms can be painful and hold strong contractions in the muscle for long periods of times, resulting in the tightening of fists, flexion of the elbow, adduction of the arm and in general high levels of stiffness. Hypotony is a condition that also can occur post-stroke where due to the abnormal changes of motor nerve control leads to slow and uncontrolled movement and the lack of resistance to passive movement resulting to impaired active movement. This can effect with the dynamic and static postural stability of the UE. (O'Sullivan, 2007.)

5.3 Tools to measure functional ability for stroke patients

Physiotherapists are needed to measure the functional ability of stroke patients. The National Institutes of Health (NIH) Stroke Scale and the Stroke Impact Scale are used to analyse weakness in the UE. These outcome measures produce information regarding to the degree of impairment for those affected by stroke but are not sensitive to mild or moderate weakness of the upper limb. (Raghavan, 2015.)

The Fugl-Meyer scale is used as a quantitative measure of motor recovery post stroke, therefore to determine disease severity and aid into personalising the treatment plan for the individuals' specific needs. It is formulated to assess motor functioning, balance, sensation and joint functioning for post-stroke hemiplegic patients. Specifically, the Fugi-Meyer scale evaluates areas concerning: motor functioning for upper and lower extremities, sensory functioning, balance, joint range of motion and joint pain. The scale consists of five domains and a total of 155 test items. (Raghavan, 2015, 599–610.)

The Brunnstrom Approach contains an arrangement of stages of recovery for patients suffering from hemiplegia after stroke. This approach outlines the synergic pattern of movement that occurs throughout recovery that soon develops into voluntary action of movements. There are six stages of consecutive motor recovery after a stroke. They include the evaluation of flaccidity, reflexes, spasticity, voluntary movement and coordination patterns in a progressive matter towards normal movement and coordination with no longer apparent spasticity. (Brunnstrom, 1970.)

The Manual Function Test (MFT) is an assessment for motor function impairment for stroke patients with an affected UE. It is also used to factually analyse the possible recovery process during rehabilitation. This measurement tool contains 32 tests that analyses arm motions and manipulative activities. The tests revolve around the measurement functional and neurological recovery for motor functions, progress of movement and simple to complex tasks of the affected UE. (Nakamura & Moriyama, 2000.)

Dynamometers have been created to measure the maximum isometric strength of the hand and forearm muscles. The measurement of grip strength for stroke patients regarding to their associated muscle strength in the arm has proven to be practical, non-time-consuming and easy to assess. (Ekstrand, et al., 2016, 400-405.)

6 MIRROR THERAPY

6.1 Origin of mirror therapy

Mirror Therapy (MT) is a therapeutic approach invented by Vilayanur S. Ramachandran to help alleviate the Phantom limb pain using a mirror box. It was made to address phantom limb by creating artificial visual feedback, or “virtual reality”, for patients who feel pain in limbs that have been amputated. The idea was to allow the patient's brain to perceive that there is physical movement occurring to the stumped limb, with similar mechanisms to how the brain perceives that there is pain. The mirror is used to trick the brain believing that the pain is being relieved by changing position of the amputated limb. The idea seems understandable if one would think that a way to help to solve against brain-stimulated pain is by brain-stimulated treatment. Evidence has shown that MT helps relieve Phantom limb pain; however the actual mechanical process of the treatment is not fully understood. (Thieme, et al., 2018.)

MT is now promisingly used to improve motor function after stroke. It requires a reflecting apparatus, such as a mirror, to exploit the brain’s preference concerning its limb position and to prioritise visual feedback over somatosensory/proprioceptive feedback. A mirror reflects movement made by the healthy limb to provoke the perception and visual feedback to the brain and shows that normal movement of the limb is occurring that of which was affected by stroke. An example of the apparatus and non-clinical setting performing MT can be seen in Picture 1. (Thieme, et al., 2018.) The brain receives and integrates somatosensory and proprioceptive information as well as the environment surrounding it. Therefore, to allow the operation of sensory events and to instruct movements and actions in space, a coherent mental representation of the body is constructed. Stroke effects the interaction of body parts and objects which may consecutively harm the brains portrayal of the affected side. This is the result of diminished motor ability leading to a degree of disability and motor impairment. MT helps to improve on representation and motor movement of the affected limb by stimulating signals in parts of the brain involving mirror neurons. This is the foundation of MT used for part of rehabilitation template to improve motor ability of the stroke-affected UE. (Tosi, Romano & Maravita, 2017.) Rachel Hains (2019) stated that the reflection of the healthy UE on the mirror may help with the motor recovery of the affected limb in a hypothesis that the mirror neurons in the brain are activated during the imitation of movements created and interact simultaneously with the motor neurons. (Hains, 2019.)

Picture 1. Mirror therapy demonstration in a non-clinical setting (Moseley, 2012)

A crossover study has been made on healthy individuals, through active performance, that distinguishes MT from movement observation therapy. The study shown that viewing an individual’s active hand, through a mirror reflection increases the excitability of neurons in the ipsilateral primary motor cortex. The excitability was significantly more than observing the inactive hand directly with no mirror. The study also has shown that there was a significant difference of viewing a mirror image of the active hand compared to viewing the active hand directly with no mirror. (Garry, et al., 2005, 118-22.)

6.2 Method

The principle of MT involves a mirror placed in the midsagittal plane of the patient in order to reflect the movements made of the non-affected limb to exert a positive influence of the stroke-affected limb. This therapy provokes stimulation for neuroplasticity to occur in the non-damaged brain regions to develop motor ability for movement and sensation. Whilst the movements are being performed with the non-affected hand, simultaneously the client must be attempting to perform the exact same movements with the affected side. This allows the encouragement for bilateral use of the upper limbs. If an object is of use during the therapy with the healthy limb, then the opposing hand should try to reproduce the same actions without the object as exact as possible. Below at Table 4, 5 and 6 shows an example of both movements, actions and tasks that can be made during MT. (Hains, 2019).

Table 4. Type of movements that can be performed in MT for the UE (Hains, 2019)

Movements
Flexion and extension of the shoulder
Flexion and extension of the elbow
Flexion and extension of the wrist
Flexion and extension of the fingers
Abduction and adduction of the shoulder
Abduction and adduction of the fingers
Internal and external rotation of the shoulder
Pronation and supination of the forearm
Ulnar and radial deviation of the wrist
Circumduction of the wrist

Table 5. Type of actions that can be performed in MT for the UE (Hains, 2019)

Actions
Squeezing and releasing of the fist

Opening and closing of the hand
Tapping of the fingers on the table
Oppose (touching) each finger to the thumb one by one
With the hand closed, lifting of each finger, including the thumb, one at a time

Table 6. Type of tasks that can be performed in MT for the UE (Hains, 2019)

Tasks
Handle objects using different types of grips, turning objects in the hand (complex rotation), picking up different small objects (beads or paper clips), put clothes pegs on the lip of a cup, insert pegs in a board, etc.
Grasp and release objects with different textures (balls, sponges, etc.)
Pick up and move various objects (balls, sticks, cubes, cup etc.) in different directions and in different pathways/sequences in order to complete the goal of a game.
Turn over playing cards
Colour, connect the dots to make a drawing, copy shapes on a piece of paper
Wipe, clean and dust the table with cloths with different textures (scouring pad, soft sponge, silk cloth, etc.)

6.3 Neuroplastic development with mirror therapy

Neuroplasticity is a feature of the brain that is highly important for physiotherapists to grasp as it is essential to use this knowledge for patient education and increase determination to use research-based methods for recovery. Neuroplasticity is a broad term that defines the ability of the brain to change structurally and functionally which is the reason for the brain being referred to as “plastic”. Knowing how to stimulate it with its various technique such as; muscle stimulation, repetitions and psychological approaches can make for a more effective motor learning response and make for a more efficient rehabilitation process. (Blažević, 2015.) MT is based on neuroplasticity due to the theory that the brain recognises visual feedback prior to proprioceptive or somatic feedback. The reflection through the mirror of the unaffected UE acts as a visual feedback necessary to simulate the primary somatosensory cortex to induce movement of the affected side. (Kil-Byung, et al., 2016, 629–636.)

Extraordinarily, the brain has the ability to re-organise itself functionally and physically as scientists have officially proven this from when the possibility to visually see inside the skull was available. The functional magnetic resonance imaging (fMRI) is the machine that opened the door to allow further examination of the magnificent wonders of the brain. This has changed the old tale that adult human brains were a physiological static organ. The fMRI confirms that humans and other animals have the ability to change the structure of their own brain in ways that can benefit them in many different ways. This reorganisation can be caused by many factors that are present in our everyday lives. Neuroplasticity is not particularly a subject that is taught thoroughly as it is simply not entirely understood yet. Exercise, rest, diet and physical activity can affect how well and efficient the brain works for us to live happier and healthy lives. When discussing structural involvement of neuroplasticity, it involves chemical or electric strengths between neuronal synapses, the points of connection between brain cells known as synaptic plasticity. (Demarin, et al., 2014.)

According to Vida Demarin et al. (2014) she states that neuroplasticity can be explained into two types: Structural and functional neuroplasticity. Structural neuroplasticity can be explained through the changes of strength of synapses between neurons which is referred to as synaptic plasticity. Synaptic plasticity is simply defined as change occurring within the synapse, however it can include the changes of protein synthetisation rate within the cell or the numerous amounts of specific processes such as long-term changes in the number of receptors for certain neurotransmitters. White or grey matter density can be visualised through MRI due to brain damage, neuronal death which occurs naturally throughout life and neurogenesis, the formation of new neurons. Functional neuroplasticity occurs through two mechanisms, learning and memory. They characterise a distinctive type of neural and synaptic plasticity that is reliant on certain types of synaptic plasticity producing permanent outcomes in synaptic effectiveness. Permanent changes are made by intracellular biochemical processes and structural adjustments during learning and memory between neurons through synaptic relationships. (Demarin, et al., 2014.)

There are two important aspects when discussing the encouragement of neuroplasticity for a stroke patient in a physical therapy point of view. Therapy for muscle activation and exercise is the most recognisable and obvious way where a patient can develop the ability to gradually recover from hemiplegia. Firstly, repeated attempts in movement can recreate the neural connections in improving that particular motion training. Repetition for motor learning is widely known to be highly effective as a general rule of thumb for all individuals, with or without injury. Secondly, where some may find to be the most important during physiotherapy studies do not particularly focus greatly upon, is the psychological encouragement. Social validation concerning to stroke patients is extremely fundamental for rehabilitation. Making sure that the patient fully understands and accepts the change that has happened to them personally, knowing that others are aware of what has happened also, most possible can release the boost their self-esteem or self-belief. These are linked closely to the neurotransmitter serotonin which can increase levels of dopamine and serotonin in the brain and can prevent self-destructive behaviour by allowing the release of emotional fixations. Therefore, becoming self-aware and increasing productivity in regaining activation for affected parts of the body. (Demarin, et al., 2014.)

Randolph J. Nudo (2013) states the importance of knowledge regarding to neuroplasticity as it strongly relates to the recovery from neurological injuries. It has become common knowledge that several weeks or even months post-brain injuries, such as stroke or trauma, initiate a flow of regenerative events leading to the formation of new connections being made in the brain. Meaning that the remaining motor cortical network goes through considerable changes in order to recover lost functions. In the motor cortex, as relearning of motor skills occur, cellular and network organisation is altered to accommodate for new function. This information brings hope for the creation of new interventional approaches to improve recovery due to this current knowledge present. Randolph J. Nudo also outlines the growing knowledge of the neuroplastic mechanism relating to behavioural experience being the most influential modulator for brain plasticity. Where basing rehabilitation on quantity and quality of motor experience, provoking the brain to be reshaped after injury in either adaptive or maladaptive ways. (Nudo, 2013, 887.)

According to Grafman Jordan (2015), neuroplasticity must be recognised with the interconnection of two aspects: from a tissue level and behavioural, cognitive level as they both work in conjunction with each other. This can be enhanced by therapeutic interventions which require concentrated effort to promote the recovery of functions that had been caused by partial brain damage. Evidence has shown that morphological synaptic changes leads to the reorganisation of local and distributed neural networks in certain parts of the brain. (Grafman, 2015, 795-802.)

Field-Fote Edelle C. (2015) provides evidence that there is possibility to amplify neuroplastic changes by non-invasive methods, such as electric, magnetic and vibration energy stimuli forms that are clinically accessible. The theory is the added stimulation of neural circuits during training enhances the promotion of neuroplasticity more than if the training was performed without it. (Field-Fote, 2015, 103-126.)

6.4 To be taken into consideration for mirror therapy

Cognitive ability is an aspect that can affect the capacity of being in a concentrated mind-set which is desired to receive the full benefits of MT. One of the key elements to be in that mind-set is for the patient to be able to follow instructions and focus on the reflection. Cognitive difficulties must be considered to those who must self-administer the mirror apparatus and the therapy at their own home. Aphasia, dementia, a mental health problem or attention deficit are examples of cognitive disorders that can hinder therapy progress. It is important for the patient to understand instructions and have ability to focus during treatment and remember the schedule of practice 30 minutes each day. Visual impairment is another factor that can negatively affect the outcome of MT. As the therapy is based on visual feedback, any deficits that has evolved during or post-stroke for the patients, eyesight may not produce the visualisation needed to produce the effects MT can accomplish. Other factors that must be considered are damage to the musculoskeletal system or peripheral nerve on the hemiplegic side that may have occurred post-stroke or during. Evidence of recent alcohol or drug abuse, severe depression, prior surgery to shoulder or neck region and serious uncontrolled medical conditions are other factors that may affect the aim for MT. (Thieme, et al., 2018.)

7 AIM AND OBJECTIVES OF THESIS

The aim of this thesis is to find out the evidence based effects of mirror therapy for stroke patients with hemiplegia regarding to their functional capacity of the upper extremity as a part of rehabilitation.

The thesis will review and analyse most recent studies to determine the usefulness of mirror therapy for the improvement of functional ability of the upper extremity.

To reach the aim for this research, the objective is going to be shown as a question supported with answers found in this literature review. The question is:

1. How is mirror therapy effecting on functional capacity for the upper extremity?

8 LITERATURE REVIEW

A literature review is an analyses and in depth evaluation of previous research. It is a summary and synopsis of a specific area of research, to allow the reader to clearly understand the meaning of creating this paper with this particular topic and the importance behind the selection of this particular research question. A literature review gathers previous research together and explains how it connects it provides answers regarding to the research question. All the quality and findings will be critically evaluated so that there will be no bias opinion, therefore areas of success and unsuccessful interventions will be highlighted. (Shuttleworth, 2009.)

The formation of a literature review shall revolve firstly around the research question. Identifying clear key words to simplify the process of finding the relevant information is fundamental. In order to create the research question, the PICO framework is used. (Khan, et al., 2003,118-121.)

P = Population. The specific population we are focused upon, such as stroke patients.

I = Intervention. An intervention, such as mirror therapy.
C = Comparison. A comparison such as a randomised controlled trial (RCT)
O = Outcome. The outcome using measurement tools.
(da Costa Santos, et al, 2007, 508-511.)

The PICO framework allows the researcher to produce clear study questions. The researcher can search each term under a similar heading. For example;
P would be STROKE – stroke patients,
I would be MIRROR THERAPY
C would be CONTROL GROUP – conventional therapy, constraint-induced movement therapy, etc.
O would be FUNCTIONAL ABILITY – functional assessment,
Using this framework can help researchers with the direction related to the research.
(da Costa Santos, et al, 2007, 508-511.)

9 STUDIES SELECTED

9.1 Search Strategy

The database search was conducted in April 2019. The search was undertaken with mirror therapy as the main heading along with the following terms: AND stroke AND hemiplegic AND/OR function/motor performance. PubMed, Cochrane Library and ResearchGate were the databases selected to perform the search. The PEDro (Physiotherapy Evidence Database) quality assessment tool was used when the search strategy was complete.

Inclusion criteria for this research involved studies dating back no more than 10 years and those of that were available as a free full text were only considered. Randomised controlled trials were ideal to obtain in this research, however due to the lack of articles collected, pilot studies were included also. Exclusions were trials that included robotic instruments to carry out the therapy.

9.2 Study Selection

During the first stage of the selection process, articles that specifically researched MT relating to upper limb function with hemiplegia stroke patients were included. Any duplicate articles were excluded. After receiving and reviewing the abstracts of the remaining articles, according to PICOS principles, 6 out of 25 articles were selected for this thesis.

The six selected studies have been gathered in the following tables. Table 7. consists of the summarisation of the type of study, PEDro rating, intervention and the different treatment plans administered in the sample and control group. Table 8. consists the description of the methods of assessment, the final results and the consequent causes of bias.

Table 7. Intervention plan, PEDro grading, sample group and control group implementations

Title, Authors and Type of Study	PEDro Grade	Intervention	Sample Group	Control Group
1. Effect of MT and electrical stimulation on UE function in stroke with hemiplegic patient: a pilot study. (Young-Rim Paik, 2017) Pilot study	4	All patients were treated with MT and neuromuscular electrical stimulation 5 days/week for 4 weeks. Participants qualified for the study when: Inclusion criteria: a) Hemiplegia after stroke b) Modified Ashworth Scale <2 c) Wrist strength poor grade or better d) No communication problems.	n pts = 8 MT = 20 minutes a day. Immediately after MT, NMES was mediate. Therapy was performed based on the previous studies.	No control group.
2. Effect of MT on UE motor function in stroke patients (Gurbuz Nigar, 2016) Randomized controlled trial	8	Total number of randomly assigned hemiplegic n pts =31 Both groups underwent conventional therapy 60–120 minutes/day, 5 days/week for 4 weeks. Inclusion criteria: a) Patients diagnosed with hemiplegia due to stroke that was unilateral	n pts = 15 MT group underwent 20 minutes/day for 5 times/week under the supervision of a therapist.	n pts = 16 The patients in the conventional group performed. the same

(RCT)		and began within the past 6 months, b) Brunnstrom stage for the UE between I and IV, c) Mini-Mental State score of ≥24 points d) Lack of excessive spasticity in the joints of the affected UE (stage ≤2 according to the Modified Ashworth Scale), and no past history of stroke. Exclusion criteria: a)Present joint movement limitations in the healthy UE b) Visual field defect or neglect syndrome c) Previously underwent a rehabilitation program.	The MT group consisted of periodic flexion and extension movements of the wrist and fingers on the non-paralysed side.	exercises against the non-reflecting face of the mirror.
3. Effect of Constraint-Induced Movement Therapy and MT for Patients With Subacute Stroke (Yoon Jin A, 2014) RCT	8	Total number of randomly assigned hemiplegic n pts = 17 All groups received conventional occupational therapy for 40 minutes/day for the same period. The inclusion criteria: a) Patients who were diagnosed with hemiplegia due to stroke (onset time less than six weeks) and no past history of stroke b) Active extension of the affected wrist and more than two fingers at an angle of >10° and an active abduction of the affected thumb at an angle of >10° c) Can have a simple communication d) Patients who can receive care by guardians or caregivers e) Maintain a sitting position >30 minutes. Exclusion criteria: a)Depression that disabled the patients to cooperate in the treatment b) Musculoskeletal problems that disabled patients to perform the active task training c) Spasticity of Modified Ashworth	n pts = 8 In CIMT combined with MT group and CIMT only group, patients wore a specially designed orthosis to suppress the motion of the unaffected UE for two weeks. MT was performed for 30 minutes/day for 5 days/week, for 2 weeks. MT included 1.Flexion/extension of the shoulder, elbow, wrist, finger, 2.Pronation/supination of the forearm according to the	n pts = 9 The control group received additional self-exercise to substitute for MT as well as the palliative rehabilitation therapy that is routinely recommended for the hospitalised patients.

		Scale II or higher d) Complex regional pain syndrome or secondary adhesive capsulitis.	verbal instructions. The patients were a suggested to perform the objective task training with the unaffected hands. Group with CIMT combined with MT did not receive the palliative rehabilitation therapy.	
4. Effect of MT on Recovery of Upper Limb Function and Strength in Subacute Hemiplegia after Stroke (Seok H., 2010) RCT	4	Total number of randomly assigned hemiplegic pts = 40 Country: South Korea Inclusion criteria: a) Stroke within 6 months Exclusion criteria: a)Patients who are not able to understand treatment instructions b) Aphasia c) Musculoskeletal or neurological damage of the unaffected UE d) Modified Ashworth Scale of 3 or more points e) Brunnstrom stage of recovery (UE) of 1 or more than 5 points.	n pts = 19 MT for the affected limb, therapy for 30 minutes 5 days/week, 4 weeks. 5 movements of wrist and fingers, each 6 minutes.	n pts = 21 No additional therapy
5. Effectiveness of MT containing functional tasks on UE motor functions among patients with stroke (Penina Langhu, 2018) Convenience	4	Total number of convenience sampling technique assigned hemiplegic & hemiparesis n pts = 60 Inclusion criteria: a) 50 to 75 years of both the sex b) UE motor impairment with hemiplegia or hemiparesis for less than one year c) Patients in stage II, III and IV in Brunnstrom motor recovery scale.	n pts = 30 MT containing functional tasks was administered for 30 minutes/day and 7 times/week for two weeks for the study group.	n pts = 30 The control group received routine care.

sampling technique		Exclusion criteria: a)Poor cognitive function b) Visual deficit and perceptual deficit c) Severe contracture in the affected limb d) Fracture on paretic extremities.	Patients were taught how to do the tasks on the first day. Simple tasks like flexion, extension, counting fingers were given for 3 days and followed by the complex tasks like picking up a coin, drawing a shape were given for 3 days.	
6. The effects of mirror therapy with tasks on UE function and self-care in stroke patients (Park Youngju, 2015) RCT	5	Total number of randomly assigned hemiplegic n pts = 30 Inclusion criteria: a)Stroke identifiable by computerized tomography or MRI b) No cognitive dysfunction indicated by a Korean Mini-Mental State Examination score >2412) c) No perceptual disorder or unilateral neglect indicated by the Motor-free Visual Perception Test d) 3 months post stroke, and e) Brunnstrom score between stages I–IV for the UE14). Exclusion criteria: a) Aphasia b) Vision or hearing disorders c) Had MT previously.	n pts = 15 The MT composed of 8 tasks and was administered 5 days/week for 6 weeks. (Use of functional tasks) Taks: 1.Reach to press switch. 2.Reach to grasp cone. 3.Grasp a small bean bag. 4.Grasp a cup. 5.Lift a plastic bottle. 6.Lift a cup 7.Put coins in the hole of money box. 8.Pick up and place stones on palm.	n pts = 15 The control group performed the same 8 tasks but with the non-reflecting side of the mirror.

MT = mirror therapy; UE = upper extremity; n pts = number of patients; RCT = randomised control trial; CIMT = constraint-induced movement therapy

Table 8. Assessment tests, study results and consequent reasons of bias

Study (Title, Authors and Year)	Assessment	Result	Bias/Discussion
1. Effect of MT and electrical stimulation on UE function in stroke with hemiplegic patient: a pilot study. (Young-Rim Paik, 2017) Pilot study	• Modified Ashworth Scale (inclusion test) • Fugl Meyer Assessment (FMA)	Before and after intervention, FMA showed significant improvement from 29.5 ± 12.4 to 36.5 ± 15.5 ($p<0.05$).	I. Procedure was not purely random. II. Allocation concealment was not stated. III. Intention to treat (ITT) analysis not stated. IV. Blinding of outcome assessment not detected. V. Assessors blinded to group allocation were not stated.
2. Effect of MT on UE motor function in stroke patients (Gurbuz Nigar, 2016) Randomized controlled trial (RCT)	• Mini-Mental State (inclusion test) • Modified Ashworth Scale (inclusion test) • Brunnstrom m otor recovery scale (inclusion test) • FMA UE score • Functional Independence Measure (FIM) self-care score	FMA and FIM baseline scores of the UE were similar between the groups ($p>0.05$) Post-treatment: Statistically significant (SS) increase in the UE Brunnstrom stages ($p=0.001$ for MT group, $p=0.008$ for conventional group) and hand Brunnstrom stages ($p=0.001$ for MT group, $p=0.006$ for conventional group). However, no SS difference between the pre- and post-treatment UE and hand Brunnstrom stages of the groups ($p>0.05$). SS improvement in both groups in FMA post-treatment compared to the pre-treatment value	I. Randomised using a random number table. II. Allocation concealment confirmed. III. ITT analysis was stated. IV. Blinding of outcome assessment was stated. V. Assessors were blinded to group allocation.

		(p=0.001 for both groups). Post-treatment FMA UE score was SS higher in the MT group than in the conventional group (p=0.047). No SS difference between the groups for the FIM self-care score post-treatment (p>0.05), but there was a significant improvement compared to pre-treatment scores in both groups (p<0.001 and p=0.001, respectively).	
3. Effect of Constraint-Induced Movement Therapy and MT for Patients With Subacute Stroke (Yoon Jin A, 2014) RCT	• The box and block test • 9-hole Pegboard test • Grip strength • Brunnstrom motor recovery scale (inclusion test) • Wolf motor function test • FMA • Korean version of Modified Barthel Index	Post two weeks of treatment: Both CIMT groups with and without MT showed higher improvement (p<0.05) than the control group, in most of functional assessments for hemiplegic UE. The CIMT combined with MT group showed higher improvement than CIMT only group in box and block test, 9-hole Pegboard test, and grip strength, which represent fine motor functions of the UE.	I. Randomised using card with numbers. II. Allocation concealment confirmed. III. ITT analysis was stated. IV. Blinding of outcome assessment was stated. V. Assessors blinded to group allocation.
4. Effect of MT on Recovery of Upper Limb Function and Strength in Subacute Hemiplegia after Stroke (Seok H., 2010) RCT	• Brunnstrom motor recovery scale (inclusion test) • Modified Ashworth Scale (inclusion test) • Manual Function Test (MFT) • Manual Muscle Test (MMT)	Post-treatment: MT group showed significant improvements in MMT, grasp and lateral pinch force of grip strength test (p＜0.05), compared to control group. Improvement in MFT was more evident in MT group (p＜0.05).	I. Randomised using computer generated random number sequence. II. Allocation concealment not stated. III. ITT analysis not stated. IV. Blinding of outcome assess-

	• Grip strength (Outcomes were recorded at baseline and after 4 weeks of treatment)		ment. V. Assessors were blinded to group allocation
5. Effectiveness of MT containing functional tasks on UE motor functions among patients with stroke (Penina Langhu, 2018) Convenience sampling technique	• Brunnstrom motor recovery stage (inclusion test) • FMA • Modified Barthel Index	Post-treatment: SS results (p<0.001) showing that the MT comparing to the control group was found effective in improving the motor function, sensation, passive joint motion and joint pain of the UE.	I. Convenience sampling technique, high risk bias. II. Allocation concealment not stated. III. ITT analysis not stated. IV. Blinding of outcome assessment not stated. V. Assessors blinded to group allocation not stated.
6. The effects of MT with tasks on UE function and self-care in stroke patients (Park Youngju, 2015) RCT	• Brunnstrom motor recovery scale (inclusion test) • Mini-Mental State Examination (inclusion test) • MFT • FIM	Post-treatment: No significant differences between groups at baseline in the MFT and FIM self-care scores (p<0.05). Both groups showed a significant improvement post-intervention. Comparison of the changes in the MFT and FIM self-care scores from baseline to 6 weeks between groups showed significant improvement in the MT group (p<0.05).	I. Randomised, not stated how. II. Allocation concealment not stated. III. ITT analysis not stated. IV. Blinding of outcome assessment not stated. V. Assessors were not blinded to group allocation.

MT = mirror therapy; UE = upper extremity; RCT = randomised control trial; CIMT = constraint-induced movement therapy; FMA = fugl meyer assessment; FIM = functional independence measure; MFT = manual function test; MMT = manual muscle test; ITT = intention to treat; SS = statistically significant

10 RESULTS

MT has proved to provide evidence for significant improvement for many different functional measures comparing to that of the control group. Therefore, the implementation of MT as part of a rehabilitation program for stroke induced hemiplegia of the upper-limb is more likely to assist in motor recovery in comparison to conventional practice. Recovery from stroke for the UE requires consistent practice to stimulate neuroplasticity in the brain for the regeneration of new motor neurons. In each of the studies involved in this thesis, MT consistently provided better results in better functioning assessment.

One research study that did not contain a control group, shown the possibility of using electrical stimulation in combination with MT. It has shown promising results which may look to further research in the future to the possible higher potential for recovery of MT with electrical stimulation. Another study that was had three groups consisting of a control, constraint-induced movement therapy (CIMT) only group and CIMT combined with MT shown promising results for the combined therapy. It showed significant improvement for the assessments specifically for fine motor functions of the UE. This suggests that MT has the potential to improve fine motor skill performance, however requires more evidence based research to make it more reliable.

It is important to recognise that five out of the six studies included in their study how long the MT intervention will be performed per week. Two studies conducted MT for 20 minutes, five times per week. Another two studies conducted MT for 30 minutes, five times per week. Finally, one study conducted MT for 30 minutes, seven times per week. Whereas one study did not mention how many minutes they have conducted their MT, however stated the patients had eight tasks to perform and did them five times a week. It is unreliable to compare if difference in time duration of MT has any possible effect of intervention outcome due to the different assessments and MT programs were used.

Out of the six studies, there were a total of twelve different pre and post assessment tests. The top four most common assessments performed were the Fugl Meyer Assessment test (FMA) (4/6), Grip strength test (2/6), Manual Function Test (MFT) (2/6) and the Brunnstrom motor recovery scale (2/6). Results have shown that MT gave significant results in improving grip strength for all of the studies that have included the test into their research. Regarding to Brunnstrom motor recovery scale, there was no significant improvement comparing conventional treatment for two out of the two studies that included it into the research. For the Fugl Meyer Assessment test, two studies reported to have a significant increase of results for the MT group comparing to the control post-treatment and the single pilot study included in this literature review reported an improvement in their results post-treatment. One of the studies out of the four that has used the FMA test reported no significant difference when comparing to the control group with conventional treatment; however it reports that finer motor skills were improved significantly more than the control group. For the studies that has included the MFT, two out of the two reported positive results of significant difference for the MT group than for the control group.

The results indicate that MT has no negative effects and has positive potential in increasing functional ability for stroke patients suffering from hemiplegia. It is a non-pharmacological and a cost effective method that does not involve negative side effects. For improving the UE motor functions, MT can be said to have potential to be effective.

11 CONCLUSION

Results have shown in this thesis that MT has potential to improve on functional ability for stroke patients suffering from UE hemiplegia. MT is a simple non pharmacological and cost effective method that has no side effects and is an easy therapy which can be done at a clinical and home setting. The studies chosen for this thesis all had their individual MT program which does not allow for a reliable comparison. Study samples can be said to be rather small also. However, all in all, MT seems to have potential to enhance ones' functional ability in some aspect and so far has shown no negative outcomes.

Research with more reliability is required to assure the effectiveness of MT to directly identify more specifically the expected outcomes for MT. This may be possible by using a larger study sample, and possibly comparing types of MT programs, such as functional tasks for fine or gross motor skills to specifically evaluate the effectiveness of MT. Using different comparisons such as meaningful tasks with basic movement strategies or looking at the type of commands given during therapy. Functional ability of the patient should be considered pre-intervention to confirm that the patient will be able to give respectable attempts of proceeding with the tasks or movements. Blinding of the patients, assessors and therapists would be necessary to eliminate any bias.

12 DISCUSSION

The topic of this thesis was chosen by the author as it was of personal interest of unidentifiable mechanisms of the brain that allow for motor recovery to occur after brain injury. MT requires the brains ability to reorganise itself through neuroplasticity to regain functional ability that has been affected due to stroke. Even though the underlying mechanisms are not exactly known to how these changes arise, they appear within all of us. From reading the literature in order to create this thesis, a growth of importance develops for individualised physiotherapy rehabilitation for stroke patients. It has been previously written in the mirror neurons section by Vida Demarin, et al. (2014, 209-211) and neuroplasticity section by Randolph J. Nudo (2013, 887) that the activation of particular parts of the brain responds more when an individual was performing a task that was familiar or somewhat meaningful to them specifically. I cannot help but to suspect possibilities for further enhancement in MT by adding individualised stimulation into the program that is somewhat more meaningful to the patient prior to them having stroke.

Beginning writing this thesis, my first duty was to direct my research question so that it would be more specific. I was concerned to the amount of research I would be able to have access to, so I was cautious to how specific the research question should be. Having confined the search criteria to patients suffering from hemiplegia and not hemiparesis could have been one main reason to the low amount of collection I have gained from my search. One unfortunate limitation whilst writing this thesis was that numerous research articles required payment to see the full article when searching on each database. This limited the amount of articles that were able to be reviewed and therefore affects the reliability of this thesis. There were not as many studies as anticipated; part of the reason could be that due to the strict and specific search criteria and that perhaps MT is still a rather new therapy method. There were a mix of different PEDro scored articles, from 4/10 to 8/10, in which I appreciate comparing studies with different scores to prevent bias.

One of the main issues with comparing the results of these studies to each other is that almost all had their own MT procedures. As different or unknown exercises and teaching methods were used for each of the studies, it is not possible to make a reliable analysation of the effectiveness of the overall MT used. However, as each study has used their own methods to carry out the procedure, they all have received somewhat positive results which show encouraging possibilities. Moreover, it is important to recognise that inclusion criteria for most of the studies that has presented its information, has shown that patients with some functional ability or with a large range of score possibilities in the Modified Ashworth Scale and Brunnstrom recovery stage were used. As exercises used in MT should be task-specific in order to specifically aid in the improvement of UE motor function, this follows up with the question "what if the patient's condition is so severe it disables the patient to minimally perform these task-specific exercises? Do we use simpler tasks? Would MT still prove to be a useful therapy treatment?"

The studies collected for this thesis are not the most reliable for comparison. The main reasons are: (1) Not all were randomised controlled trials (one pilot and one convenient). (2) Not all were simply comparing MT and the controlled conventional therapy (one contained the involvement of electrical stimulation, one was combined with CIMT and one did not have a control group). (3) Inclusion and exclusion criteria differed. (4) Different assessment measures were used which made comparison of results challenging. (5) Each study used different MT programs. (6) Duration of therapy was not the same to each study. (7) Commands to therapy were not specified. (8) Severity of the patient's condition differed. For more effective and reliable results, future studies would rather require a larger number of participants into their study or more studies performing the same assessment measures and MT program for easier and more reliable evaluation.

Future research for MT should involve specific MT program combined with various movements and functional tasks that the latest research has shown to produce effective results. Specific functional outcome aims should be specified in relation with choosing the correct and most reliable assessment method. Also, future research could consider investigating more about the further possible benefits of combining electrical stimulation with MT. As MT is dependent on stimulating the CNS for recovery, there could be other ways during the therapy that can help provide for a stronger stimulation, perhaps such as including tasks that are more individualised and meaningful to the patient, or including other senses like smell and sound. Possible changes to the environment or therapy setting to enhance stimulation. Also, I believe that how the therapy is instructed and guided plays a big part in the meaningful participation of the patient which is an important aspect for stimulation. This could also be an important factor to how giving a systematic guidance and protocol can play an important role for individualised patient recovery. However, firstly there must be sufficient well-designed randomised controlled trials to assure MT effectiveness before adding further stimulation.

I would advise for a follow-up of this research by involving research that has focused directly upon the type and quality of exercises given to the patients MT program. To involve during MT individualised stimulations in order to bring out the most of possible outcome, taking account all kinds of possible meaningful activities and different sensations that are special for each individual patient. Also, the high consideration of the functional ability the patients have and the severity of their condition prior to MT (such as the presence of active movement). As this thesis has shown that MT involves neuroplasticity and the communication between the sensory and motor cortex, in order to improve motor pathways signals. In my opinion, possibly stimulating other parts of the brain that holds the persons own conscious identity through memories and what makes up their personality can enhance the neuroplastic changes as the sensory cortex does for the motor cortex. All in all, the brain functions and communicates as a whole unit, therefore considering other sensations and techniques to enhance neuroplasticity of the brain to stimulate a faster recovery.

One advice I would of liked to have followed prior to getting into depth of writing into my thesis. Was to find at least five research articles that studied the same topic as the thesis and to find the similarities between them of what information the researchers had written. I believe that this would have helped me to be more directed to what information I should focus upon and therefore be more efficient with time.

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