ASSOCIATION BETWEEN SENSORY OF FINGERTIP AND HAND FUNCTION IN INDIVIDUALS WITH STROKE

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A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Science in Physical Therapy

Department of Physical Therapy

FACULTY OF ALLIED HEALTH SCIENCES

Chulalongkorn University

Academic Year 2021

ความสัมพันธ์ระหว่างการรับสัมผัสปลายนิ้วและการทำงานของมือในบุคคลที่มีโรคหลอดเลือดสมอง

น.ส.ออริสา เอลฟาธ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชากายภาพบำบัด ภาควิชากายภาพบำบัด
คณะสหเวชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2564

Thesis Title	ASSOCIATION BETWEEN SENSORY OF FINGERTIP AND HAND FUNCTION IN INDIVIDUALS WITH STROKE
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Field of Study	Physical Therapy
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ความสัมพันธ์ระหว่างการรับสัมผัสปลายนิ้วและการทำงานของมือในบุคคลที่มีโรคหลอดเลือดสมอง. (ASSOCIATION BETWEEN SENSORY OF FINGERTIP AND HAND FUNCTION IN INDIVIDUALS WITH STROKE) อ.ที่ปรึกษาหลัก : อัญชลี ฝูงชมเชย

สาขาวิชา	กายภาพบำบัด	ลายมือชื่อนิสิต .....
ปีการศึกษา	2564	ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

6270014037 : MAJOR PHYSICAL THERAPY

KEYWORD:

Orisa Elfath : ASSOCIATION BETWEEN SENSORY OF FINGERTIP AND HAND FUNCTION IN INDIVIDUALS WITH STROKE. Advisor: ANCHALEE FOONGCHOMCHEAY

Field of Study:	Physical Therapy	Student's Signature .....
Academic Year:	2021	Advisor's Signature .....

ACKNOWLEDGEMENTS

Orisa Elfath

First and foremost, I would like to praise Allah the Almighty, the Most Gracious, and the Most Merciful for His blessing given to me during my study and in completing this thesis. May Allah's blessing goes to His final Prophet Muhammad (peace be up on him), his family and his companions.

Countless people supported my effort on this thesis. Especially Assistant Professor Anchalee Foongchomcheay PT. Ph.D. has been an ideal teacher, mentor, and thesis supervisor, offering advice and encouragement with a perfect blend of insight and humor. I'm proud of, and grateful for, my time working with lovely Ajarn.

Thank you to my committee members, Assistant Professor Sujitra Boonyong PT., Ph.D. and Dr. Pagamas Piriyaprasarth. Your encouraging words and thoughtful, detailed feedback have been very important to me. Thank you to the interviewees, who so generously took time out of their schedules to participate in my research and make this project possible.

Thank you to National Brain Center Hospital Indonesia for allow me to do the research here and thank you to Miss Suci for all of the kind words and assistance you have Provided

Thank you to my parents, for your endless support. You have always stood behind me, and this was no exception. Mom, thank you for fielding a ridiculous number of phone calls, for calming me down, and for proofreading anytime, anywhere. Dad, thank you for all of your love and for always reminding me of the end goal. Thank you for your prayers and countless hugs, it makes me strong every time.

Thank you to my brother and his wife for always being there for me and for telling me that I am awesome even when I didn't feel that way.

Thank you to my husband, Ramdhan Setiawan, for constantly listening to me rant and talk things out, for proofreading over and over (even after long days at work and during difficult times), for cracking jokes when things became too serious, and for the sacrifices you have made in order for me to pursue a Master's degree. Thank you for your support since my first step, whenever you told me that I can achieve my dream, it's like giving me a new hope.

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CHAPTER I

INTRODUCTION

1.1 Background and Rationale

Stroke is characterized by neurological deficit to an acute focal injury of the central nervous system (CNS) by vascular damage such as cerebral infarction, intracerebral hemorrhage (ICH), and subarachnoid hemorrhage (SAH). Stroke case is a major cause of death and disability in worldwide (1). In America, a report from the American Heart Association shows there were 7 million people who age above 20 years old had a stroke. The overall prevalence is 2.5%, and the number of people experiences a new or recurrent stroke each year was around 795,000 with approximately 610,000 of these are first attacks, and 185,000 are recurrent attacks. From 2004 through 2012, the number of stroke incidence was increased by 41.5% for males aged 35-44 (2). An increase in the prevalence of stroke also occurred in Indonesia. The Prevalence rises from 8.3 per-1,000 (2007) to 12.1 per-1,000 (2013) (3). In another country, Thailand, the prevalence of stroke is 18.8 per-1000 in people over 45 years (4). In this country, stroke is the first leading of death. The mortality rate data from The Ministry of Public Health in Thailand is increasing during the past five years. The mortality increased from 20,8 per-100,000 (2008) to 30.7 per-100,000 (2012). This may reflect the expanded rate of stroke in Thailand (5). In the end, there was 10,983,301 cases of stroke for global prevalence. There was a significant increase in the absolute number and prevalence rate, from 5,782,226 in 1990 to 10,983,301 in 2013. Although the global prevalence of stroke was increase, the number of total stroke deaths in developed countries was declined. A significant raise in the number of deaths from stroke among young adults was detected in developing countries (6).

In the data presented by Riset Kesehatan Dasar (RISKESDAS) 2018 from the Health Ministry of Indonesia, stroke case is a disease that results in a high rate of dependency as a consequence of stroke damage that makes disability in the stroke sufferers. The rates for overall stroke suffers in Indonesia were 36.33% for independence, 33.25% for mild dependence, 7.10% for moderate dependence, 9.43% for severe dependence, and 13.88% for full-dependence (7). The high level of

independence is the cause of disability that occurs due to brain damage after a stroke. In classifying disability, various related factors should be depended on the localization of the lesion, the level of neurological recovery, the patient's premorbid status, and the environmental support system. The most common condition seen in stroke patients in the rehabilitation phase is contralateral hemiparesis or hemiplegia. Other neurological manifestations vary depending on the site of the stroke lesion and whether a stroke occurs in the cerebral hemisphere or brain stem. There is a large degree of specialization in the brain with different neurological functions. The clinical picture of stroke depends on the specific area that has been damaged with the loss of specific neurological functions they control. When damage occurs in one area of the brain, not only the specific part associated with the affected area are affected, but also the whole brain suffers from loss of input from the injured part (8).

The different area of the brain has a different function, such as the right hemisphere that controlled the left-side body functions (and vice versa). In most people, the left hemisphere control language function to communicate by voice and writing. Basically, the language function localized in the dominant hemisphere. The vast majority people in the world is right-handed people just about half of left-handed people are left-brain dominant. Damages to the motor cortex by a stroke are responsible for severe physical problems that arise; the decrease of muscle tone, low movement control ability, hyporeflex problem, and may be very troublesome for some patients (9).

There are two types of UMN lesions of a stroke that happen after stroke onset. The types are consequences of UMN syndrome. The first type is "positive" UMN sign that represents excessive muscle tone and stretches reflex. The second type is "negative" UMN sign that represents weakness, impaired motor control/planning, impaired coordination, and easy fatigability. These positive and negative consequences of stroke will interact with each other and will cause secondary impairments in the patients. During the recovery phase, the symptoms will produce a dynamic clinical presentation (10). For example, after stroke onset, some patients get flaccid. The flaccidity resulted in immobilization and caused shoulder depression as a secondary impairment. The patients receive rehabilitation program, and during this phase, the muscle tone rises up to high muscle tone. This clinical presentation is a

Brunnstrom stage of motor recovery after stroke. Basically, motor recovery starts immediately after stroke onset, then follows a relatively predictable pattern, regardless of the stroke types (hemorrhagic or ischemic and cortical or subcortical) (10, 11). On the other hand, stroke survivors also have poststroke sensory dysfunction (PSSD) problem from 11% to as high as 85% (12).

The second type, "negative" UMN sign, represent low muscle tone that makes patients have no power to act or move. Sensory and motor loss are the biggest problem of this impairment and have correlation with each other. Each type of somatosensory stimulations has been shown facilitate motor behaviour *such* as stimulation on peripheral nerve, vibration on muscle-tendon, paired associative stimulation and tactile learning improve motor performance by increasing corticospinal excitability and enlarging the representation of the stimulated body part in the primary motor cortex (M1) (13).

Previous research proved that stimulation in the sensory systems contribute to motor improvement. Motor stimulation is also processed centrally for conscious sensation, besides primarily for monitoring motor performance, it is also for unconscious reflex adjustment of posture and muscle tone. On the other hand, somatosensory information also gives input for the motor system. The main sources of somatosensory information that acts as a feedback to the motor system are muscle spindles, Golgi tendon organ (GTO), and low-threshold mechanoreceptors of the skin and tendons (14). The important point of topic discussion for future research is how about the correlation between specific sensory on the fingertip with handgrip strength and FMA-UE Hand so we can know how strong the correlation is and decide the measurement and priority exercise types that increase hand motor ability and predict functional outcome (15). The best somatosensory receptor area of the skin is on the fingertip area because the fingertips have a thick density of neurons, so it is the most sensitive sensory area in the part of the body (16). The fingertip senses of participants was assessed by Two-point discrimination (2PD). 2PD test has inter-rater reliability at an acceptable level (17). This sensory aspect can support the motor performance of the people .In detecting motor performance specifically, many previous studies proved about the advantages of grip strength ability in people with stroke (18). The functions of handgrip strength assessment are to measure the ability to grip that means

the ability to carry or to squeeze something. Handgrip strength assessment also has clinical results that can be a benchmark for the rehabilitation progression (19) because hand grip ability represents global upper extremity function (18).

Sensory and motor systems are the biggest contributor s to movement or activity. The ability to execute activities of daily living is the most important in human life. For stroke survivors, it is quite hard to do activity daily living because participant needs good motor ability to execute the motion. Gaining the ability to act and move are the main purpose for patients undergoing physical therapy training. With a good measurement, physical therapists can assess specifically and accurately so they can set the training program and monitor a progression of the program (20).

The aim of this study is to determine if there is any association between sensory and motor in specific region. This study looks at the extent to which sensory contributes to motor execution as proven in previous studies that the stimulus sent to the sensory area will provide input to the motor area, especially in this study is the hand function (21). Besides, after finding about association between specific sensory and motor, we need to find how strong grip strength ability impact to the hand functional activity. Thus, after we prove this, we find out how sensory of fingertip influences grip strength and how strong grip strength plays a role in hand function. Furthermore, this study suggests measurements or parameters that can help the therapist to look for specific problems, predict outcomes, and monitor progress in a simple but accurate way on more specific sensory and motor hand problems.

1.2 Research Question

Is there any association between hand sensory of fingertip and hand function in the paretic hand of individuals with stroke?

1.3 Objectives of The Study

This study consists of two objectives:

1.3.1 To find the association between two-point discrimination (2PD) and grip strength

1.3.2 To find the association between 2PD and fugl-meyer assessment upper extremity hand (FMA-UE Hand)

1.4 Hypothesis of The Study

This study consists of two hypotheses:

1.4.1 H_0: There is no association between hand sensory by 2PD and hand motor by grip strength

H_a: Hand sensory by 2PD and hand motor by grip strength have a good association

1.4.2 H_0: There is no association 2PD and hand function by FMA-UE Hand

H_a: Hand sensory by 2PD and and hand function by FMA-UE Hand have a good association

1.5 Expected Benefit and Application

The findings of the present study are useful for: (1) identify specific problems for chronic stroke case; (2) developing asssessments to monitor hand sensory and motor performance to reach good ADL fo troke patients.

1.6 Conceptual Framework

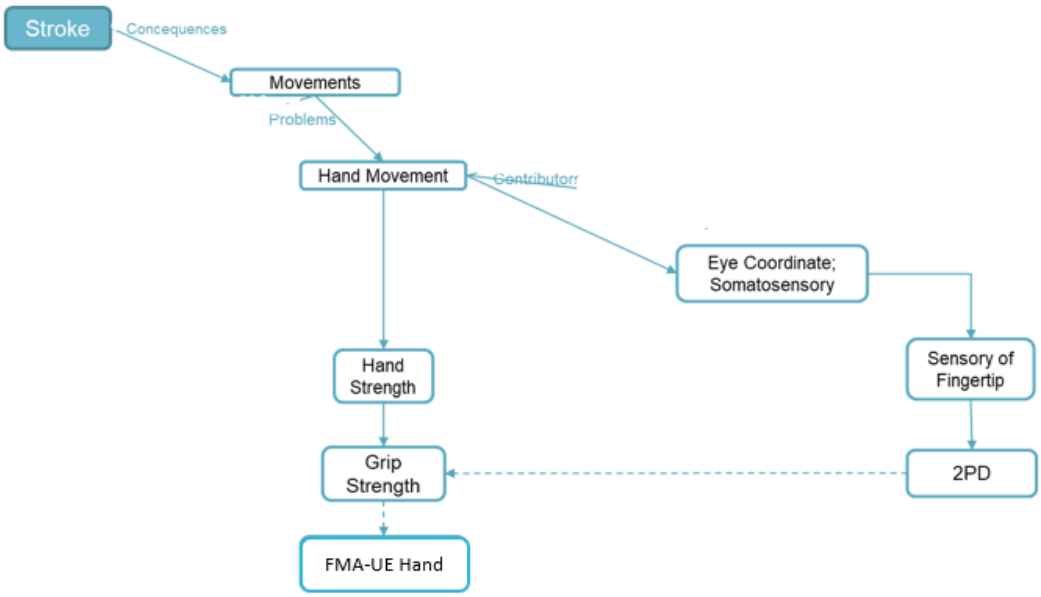

Figure 2. Conceptual Framework

CHAPTER II

LITERATURE REVIEW

2.1 Brain Function

Brain Function underlying somatosensory process divided into multiple processing levels, including peripheral neurons, spinal cord, brain stem, and the forebrain(including cerebral cortex and thalamus) (22).

2.1.1 Peripheral Neurons

Specific sensory information from skin, muscles, and joints. These sense organs or receptors in the skin and in the musculoskeletal system leading from them into the central nervous system (CNS) by neurons. The receptors in the skin and in deep tissues are either free or encapsulated. Exteroceptors, located in the skin, and proprioceptors in muscles and connective tissue around the joints.

High-threshold receptors usually signal impending tissue damage and are termed nociceptors. In addition to signaling impending acute tissue damage, nociceptors probably play an important role in monitoring the composition of the tissue fluid and thus contribute to bodily homeostasis. Thermoreceptors respond to even very small changes of the temperature of their surroundings (especially in the skin). They are much less sensitive to steady-state temperature. Low-threshold mechanoreceptors in the skin and in the deep tissues share many physiological properties. Capsular elements and membrane receptor proteins determine whether the receptor is rapidly or slowly adapting. Cutaneous low-threshold mechanoreceptors are of four types: Meissner corpuscles reside in the dermal papillae of glabrous skin (e.g., on fingertips) and respond to the slightest impression on the skin. Like Meissner corpuscles, Merkel disks respond to small impressions of the skin but are slowly adapting. Ruffini corpuscles are located in the dermis and respond to stretching of the skin. They are slowly adapting, and probably signal the steady tension. Pacinian corpuscles are large, lamellate structures located on the transition between the dermis and the subcutaneous tissue. They are extremely rapidly adapting and are well suited to signal vibration.

Among proprioceptive low-threshold mechanoreceptors, the muscle spindles are the most elaborate. They consist of a small bundle of thin, so-called intrafusal muscle fibers encircled by sensory nerve endings. Although each muscle spindle is much shorter than the

muscle in which it lies, it is connected with connective tissue strands to both tendons of the muscle. Signals from muscle spindles contribute to reflex control of movements and to kinesthesia—that is, our conscious perception of joint positions and movements. Tendon organs are located at the each musculotendinous junction, and measure the force of muscle contraction. Joint receptors are located in the fibrous joint capsule and in ligaments around the joints. They can signal movements and steady positions but their contributions to movement control and kinesthesia are not well understood.

The ventral branches of the spinal cord form the plexus that supplies the arms and legs. Each nerve emerging from these plexuses contains sensory and motor fibers arising from several segments of the spinal cord. Nevertheless, the segmental origin of the fibers remains present in their peripheral dissemination. Thus, sensory fibers of one dorsal root supply a distinct part of the skin. The area of skin that is supplied with sensory fibers from one segment of the spine is called the dermatome.

2.1.2 Spinal Cord

In humans, the nervous tissue of spinal cord is 40-45 cm long-cylinder with approximately same thickness as a little finger. It extends from the lower end of the brain stem at the level of upper end of the first cervical vertebra down the vertebral canal to the upper margin of the second lumbar vertebras. It is called medullary conus. But in children, the spinal cord extends caudally which reaches to the third lumbar in newborn. The spinal cord is somewhat flattened in the anteroposterior direction and is not as thick as the length. Generally, the thickness decrease caudally but there are two marked intumcences: cervical and lumbar enlargements. The intumcences supply the extremities with sensory and motor nerves.

The midline along the cord's anterior side named anterior (ventral) median fissure. Some of the vessels of the cord enter through this fissure and penetrate deeply into the substance of the cord. The posterior aspect of the cord named posterior (dorsal) median fissure, on each side there are shallow, longitudinal sulci anteriorly (anterior lateral sulci) and posteriorly (posterior lateral sulci). These laterally placed sulci mark where the spinal nerves connect with the cord.

The axons mediating communication between the CNS and other parts of the body; peripheral nerves. The axons (nerve fibers) leave and enter the cord in small bundles called rootlets. Several adjacent rootlets unite to a thicker strand, called a root

or nerve root. In this manner, rows of roots are formed along the dorsal (posterior) and ventral (anterior) aspects of the cord. In every dorsal root contains the cell bodies of the sensory axons that enter the cord through the dorsal root. The ventral and dorsal roots interflow to form a spinal nerve. In total, 31 spinal nerves are present on each side, forming symmetrical pairs consisting of 8 pairs of cervical nerves, 12 pairs of thoracic nerves, 5 pairs of lumbar nerves, 5 pairs of sacral nerves, and only 1 pair of coccygeal nerves.

2.1.3 Brain Stem

The brain stem is categorized into 3 structural components; medulla, pons, and midbrain. The brain stem is the earliest part of the brain and facilitates many critical neurological functions. The brain stem forms the stalk from the cerebellum and cerebral hemisphere sprout. The brain stem fibers and cells are the parts that function to convey back and forth information from the cerebrum to the spinal cord and cerebellum. This part of the brain is quite important in controlling many critical body functions such as blood pressure, breathing, and alertness. While the brain stem is considered the earliest part of the mammalian brain, it is also the most important to live. Many people still can survive if there is cerebrum or cerebellum damage, but damage to the brain stem is usually means rapid death (23).

2.1.4 Cerebral Cortex

The outer layer of neuronal tissue that makes up the cerebrum of the human brain is known as the cerebral cortex or plural cortices, commonly referred to as the cerebral mantle. These are separated into two cortices, by a longitudinal fissure that divides the cerebrum into the left and right hemispheres. The two hemispheres are joined underneath the cortex by the corpus callosum. The cerebral cortex is the site of the greatest nerve integration in the central nervous system. In the human brain, the majority part of the cerebral cortex is not visible from the outside, but buried in the sulci [6]. Moreover, the insular cortex is completely concealed. The primary sulci and gyri demarcate the divisions of the cerebrum into brain lobes. The cerebral cortex has between 14 and 16 billion neurons.

The cerebral cortex is generally divided into 4 lobes that can be found in each hemisphere; frontal, parietal, occipital, and temporal. Two other essential regions in the cerebrum are the insula, which is located deep within the lateral sulcus, and the other one is cingulate gyrus on the medial surface of each hemisphere. The cerebral cortex consists of cortical gray matter, a corrugated surface, which is laminated and has six layers, broken down into several gyri, separated by spaces or narrow grooves, sulci. There are 12-15 billion cortical neurons found in the gray cortical mantle (24).

The frontal lobe is located in the anterior portion of the brain (25). There is a gyrus precentral that is found in front of the central sulcus and coincides with the motor cortex (MI) that specifically has the function for voluntary movement execution. Many fibers in the pyramidal tract come from the precentral gyrus, and most of them cross the midline on their way to the spinal cord. The postcentral gyrus, located at the posterior to the central sulcus is the large receiving region for sensory inputs from the musculoskeletal system, the skin, and the viscera. This region is called the somatosensory cortex (SI). The tracts that send impulses from the sensory organs to the cortex are also crossed. A part of the pathways from a sense organ to the postcentral gyrus is named the medial lemniscus. The fibers of the medial lemniscus terminated in a subdivision of the lateral thalamic nucleus and neurons in the lateral thalamic nucleus convey their axons to the postcentral gyrus. Precentral gyrus damage in one hemisphere will cause paralyze in the contralateral body parts and postcentral gyrus damage on one side leads to lowered sensibility on contralateral body parts (26).

The occipital lobes (around the fissure, the calcarine sulcus) is located in the visual cortex that the primary cortical area receiving visual information. The information starts in the retina and conducts in the optic nerve and the optic tract to the lateral geniculate body and comes to the visual cortex. The visual cortex can be distinguished from the surrounding parts of the cortex in sections perpendicular to the surface: it contains a thin whitish stripe running parallel to the surface (caused by a large number of myelinated fibers). Because of the stripe, this part of the cortex was named the striate area by the early anatomists (26).

The superior side of the temporal lobe is the auditory cortex area. There is a cortical region receiving information from the cochlea in the inner ear. Medial

portion of the temporal lobe is the place for the hippocampus and cortical regions that interest in learning and memory (26). Generally, this lobe has functions that associated with learning, smell, and hearing (25).

The parietal lobe is the posterior to the frontal lobe for the sensory cortex area and some optic radiations that bring impulses from the eyes for visual interpretation. Impairment in this area can be clinically shows the loss of superior contralateral vision sign (25).

The caudate, putamen, and globus pallidus make up the basal ganglia, whose major role is movement coordination. The system of limbic consists of the amygdala, hippocampus, and the cingulate gyrus. These areas are important in memory and emotion (amygdala and cingulate) and play a role in memory and learning (hippocampus). These structures are located within the cerebral cortex and closer to the core of the brain (25).

2.1.5 Thalamus

Thalamus located in the diencephalon (area between the brain stem and cerebrum). Thalamus is important to sensory function, as almost all sensory impulses pass through this part of the brain before being directed to the cerebrum. The thalamus receives information from structures such as the basal ganglia, limbic system, and the cerebellum. Thalamus also receives impulses from the cerebral cortex so that feedback can be relayed. The thalamus is connected to all the substantial areas of the brain. Meanwhile, the hypothalamus controls important functions of everyday life (ex: hunger and thirsty), including certain autonomic and endocrine functions. The pineal and pituitary are critical endocrine structures that modulate some hormones in addition to helping with the sleep-wake cycle (27).

2.2 Brain Vascular Neuroanatomy

The brain necessitates about 20% of the body's oxygen supply and approximately 18% of the blood volume in the body circulates in the brain, which

accounts for about 2% of the body weight. The brain circulation can be divided into anterior and posterior components. The carotid arteries form anterior circulation, and the vertebral arteries form posterior circulation. The anterior and posterior circulation together merge and form the Circle of Willis. Circle of Willis is a circular ring in which several major blood vessels appear to supply blood flow to the brain (25). The blood transports oxygen, nutrients, and other important substances for good functioning of brain tissues and brings away metabolites. Brain has a crucial time about 15 seconds if blood flow to the brain has stopped, it will cause loss of consciousness. Furthermore, it will unrepairable if brain damage in 5 minutes. Each brain vessel tends to irrigate specific parts of the brain, and each part has specific stereotyped syndromes. Imaging studies can suggest the location of the vascular lesion. In most cases, thrombolysis in the initial hours after stroke onset can restore blood flow and improve clinical status. Early detection and treatment of stroke are supremely important (28).

2.2.1 Anterior Circulation

The right and left carotid arteries supply anterior cerebral circulation. The body of internal carotid travels to the circle of willis and divide into two cerebral arteries. The middle cerebral artery (MCA) supplies blood to the parietal, temporal, and occipital lobes, as well as a portion of the frontal lobe's small site. The other artery also arise from MCA is lecticulostriate arteries which supplies the internal capsule and basal ganglia and known for their nature of progressive arteriosclerosis leading to stroke. The second is anterior cerebral artery which supplies a small area that localized to the medial part of the frontal and parietal lobes (29).

2.2.2 Posterior Circulation

The right and left vertebral arteries mainly supply the posterior circulation of the brain; however, the anterior spinal artery also vascularises in a small portion of the brain stem. The portion of the vertebral artery is directly responsible for feeding the most caudal part of the brain stem. At the level where the medulla meets the pons, the vertebral arteries fused to form the basilar artery. The basilar artery provides circulation to the remainder of the brain stem in addition to the cerebellum. It is

important to know some arteries that arise from the posterior circulation at the level of the basilar artery which supplies the cerebellum, as obstruction of these arteries leads to specific clinical syndromes. The most superior is the superior cerebellar artery, then below is the anterior inferior cerebellar artery (AICA), and finally near the level where the vertebral arteries give rise to the basilar artery is the posterior inferior cerebellar artery (PICA). The basilar artery rounds off by dividing into the left and right posterior cerebral arteries that pervade the posterior portion of the Circle of Willis and allow for communication with the anterior blood supply (29).

2.2.3 Venous Circulation

The venous circulation does not get as much attention as the arterial system because cerebral venous thrombosis is an uncommon form of stroke. It is advantageous to understand the venous drainage system, however, as occlusion can lead to acute stroke symptoms and significant morbidity and mortality. The superior sagittal sinus, straight sinus, and transverse sinus converge at the confluence of sinuses near the occiput. The transverse sinus communicates with the sigmoid sinus, allowing for venous drainage into the internal jugular vein (29).

2.3 Stroke

2.3.1 Definition of Stroke

The definition of stroke used by world health organization (WHO) since 1970 and still used today is rapidly growing clinical indications of localized (or worldwide) impairment of cerebral function, lasting more than twenty-four hours or resulting in death, with no evident cause other than vascular origin. (30). Basically, stroke symptoms are characterized by neurological deficits specifically to an acute focal injury of the central nervous system (CNS) by vascular damage; cerebral infarction, intracerebral hemorrhage (ICH), and subarachnoid hemorrhage (SAH). Stroke is one of the leading global causes of disability and death. (1).

2.3.2 Classification

Commonly, stroke is divided into 2 classifications. The first one is ischemic stroke and another one is a haemorrhagic stroke. Generally, the incidence rate for

ischemic strokes higher than hemorrhagic stroke. It is about 80% for ischemic stroke and 20% for hemorrhagic stroke but the actual proportions is still depend on population (30).

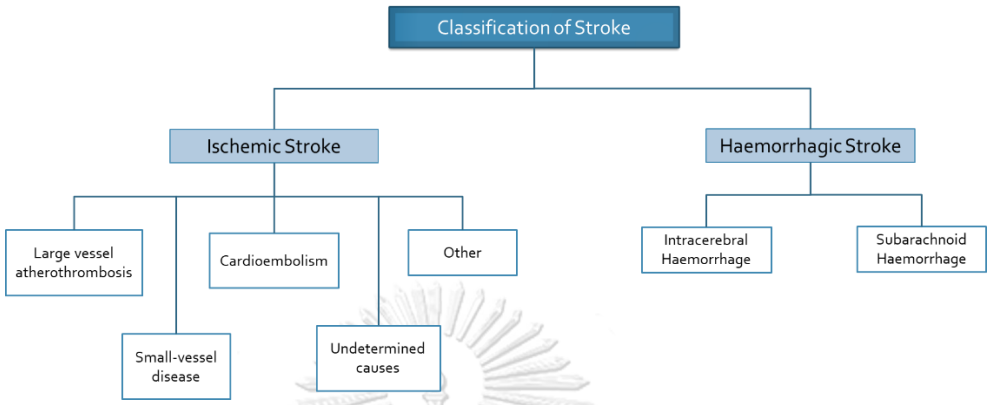

Figure 1. Classification of Stroke

2.3.2.1 Ischemic Stroke

Ischemic stroke happens because of the blood supply to part of the brain is reduced that may cause dysfunction of the brain tissue in that area. This may be due to clogged arteries from blood clots (thrombus) or blocked blood vessels (atherosclerosis), commonly happen is cholesterol plaques are deposited within the walls of the arteries, narrowing the inside diameter of the artery (31).

A system for ischemic stroke subclassification categorization, mainly based on etiology and the mechanism and the TOAST, or as it is often known, Trial of ORG 10172 in Acute Stroke Treatment is the most widely used. Based on the TOAST criteria, ischemic stroke can be grouped into five main pathological or etiological types (30, 32).

The TOAST classification with the most widely used includes:

1) Large-vessel atherothrombosis; this classification pertains to lipid-laden atherosclerotic plaques on the wall inside of a large vessel that affect intracranial and extracranial arteries (33). The most common sites for atherosclerotic plaque formation include where the carotid artery divides beginning of the vertebral arteries and path of the middle cerebral artery In atheroembolism, a thrombus forms on the vessel wall, breaks apart, and sheds clot fragments, which are carried

downstream and placed in branches of smaller arteries, resulting in several small scratches within the expected region of the parent vessel (34).

2) Small-vessel disease; refers to an occlusive condition affecting the brain's microcirculation. Common sites for small-vessel disease include deep areas of the hemispheric white matter; the region of white matter known as the internal capsule, adjacent to the proximal middle cerebral artery and close to the proximal middle cerebral artery and nourished by its branches that penetrate it; the pons in the midbrain, supplied by penetrators arising from the basilar artery; and the thalamus, which is primarily dependent on the branches of the posterior cerebral arteries. (35). Infarction in this area is small (<1.5 cm) and depends on its location in the brain, usually producing one of the classic lacunar syndromes (36):

a. Ataxic hemiparesis (one-sided weakness with excessive clumsiness on the same side)
b. Mixed sensorimotor
c. Pure motor symptoms (usually involving the face and arm or arm and leg, 33–50% of all small-vessel strokes are facial-arm or arm-leg) (37)
d. Pure sensory
e. Clumsy hand dysarthria, clumsiness of either hand out of proportion to any limb weakening, accompanied by slurred speech (38)

3) Cardioembolism happens when blood clots, which may have formed in the heart, break away, enter the bloodstream, and then become trapped in an artery of the brain. Clots can form in the heart due to intracardiac blood stasis (such as atrial fibrillation) or adhesion to a thrombogenic device or lesion (e.g. an implanted prosthetic valve) (39, 40).

4) Undetermined causes; includes people for whom a comprehensive screening for cardiac conduction or structural problems, intracranial or extracranial large-artery stenosis, or other diseases does not identify a cause (41, 42). About 40% of ischaemic strokes are of undetermined cause (43). When clinical examination and neuroimaging indicate a superficial or big, deep cerebral infarct, but none of the aforementioned regular vessel-imaging, cardiac, or hematological testing identify the potential causes of stroke, a stroke may be deemed cryptogenic (44). Recent medical

literature refers to cryptogenic embolism as Embolic Stroke of Unknown Origin (ESUS) (45).

5) Other determined causes; some types of stroke caused by extracranial artery dissection, nonatherosclerotic vasculopathy, hypercoagulable states or hematological disorders (32).

2.3.2.2 Hemorrhagic Stroke

That happens when there is bleeding from a vessel in the brain (intracranial) or vessels on the surface of the brain that lead to the space between the skull and the brain (subarachnoid), subarachnoid hemorrhage occurs due to trauma or rupture of blood vessels in the brain. Bleeding that occurs in the brain cause damage to tissue through a mass effect and neurotoxicity of blood components. Hemorrhage stroke can result in sudden increased intracranial pressure leading to herniation and death (46-48).

2.4 Sensory System

2.4.1 Somatosensory System

Somatosensory pathways from the trunk and extremities run in the spinal cord, and there are transmitting impulses from the face to the trigeminal system. Somatosensory pathways can be subdivided into three different functions: (1) transmission of specific information from the type, intensity, and localization of a sensory inputs; (2) Initiation of arousal, affective, and adaptive responses to the stimulus; and (3) unconscious monitoring and control of motor execution (14, 49).

The first group pathway called as direct pathways. This pathway is generally clinically tested because it indicates lesions in the nervous system. The types of direct pathways are: (1) the direct dorsal column pathway, that is in the transmission of tactile discriminative and conscious proprioceptive inputs; and (2) spinothalamic tract, that in the transmission of pain and temperature sensation. These direct pathways comprise three orders of neurons (14, 49).

The first-order neurons are the receptors neurons, they are derivatives of nerve peaks. Their cell bodies are outside the central nervous system in dorsal root ganglia (spinal nerves) or sensory ganglia (cranial nerves), and their axons out into peripheral

branches and central branches. The peripheral branch supplies sensory nerves and and supplies receptor organs with nerve endings. The central branch enters either the spinal cord or the brainstem by a dorsal, or sensory, root. The skin area innervated by a single dorsal root is called a dermatome (14, 49).

The nuclei of the medulla contain the cell bodies of second-order neurons found in the embryonic alar plate areas, that is, in the gray matter of the dorsal horn of the spinal cord. The axons of these neurons decussate (cross the midline) and continue cephalad. As they climb to the spinal cord, the axons of first- or second-order neurons are organized into tracts (fasciculi) situated largely in the white matter (funiculi) of the spinal cord. Via the brainstem, the axons of second-order neurons climb in tracts (some of which are called lemnisci) to the thalamus, where they terminate in specific sensory nuclei. Along their ascending trajectory, these sensory channels maintain a somatotopic arrangement, so that both the pathways and relay stations depict the body's surface topographically. (14, 49).

The cell bodies of third-order neurons within the thalamic sensory relay nuclei. Included in the ventral posterior complex of the thalamus are somatosensory thalamic neurons, including the ventral posteromedial nucleus for facial sensory inputs (via the trigeminal system). Similar to other relay stations, thalamic relay nuclei are organized somatotopically and sub-modality-specifically. . Axons of somatosensory thalamic neurons pass via the thalamocortical radiation to the primary somatosensory cortex of the parietal lobe (14, 49).

The main somatosensory cortex is located in the parietal lobe's postcentral gyrus. and is responsible for discriminative features of somatic sensory impulse receipt and evaluation. Each of its at least four functionally separate regions contains a comprehensive somatotopic map. Fibers end in an ordered form in the postcentral gyrus, with the lower extremity portrayed on the hemisphere's medial surface and the arm and hand on the lateral surface. The suprasylvian area contains images of the face, mouth, and tongue (14, 49).

An important characteristic of the somatosensory and other sensory cortices is the dynamic, use-dependent cortical plasticity of the body map representation. The shape and size of representation of certain body parts can be modified in response to

peripheral injury or training. Representation of pain in the cortical occurs not only in the parietal cortex but also in the insular cortex and the cingulate gyrus (14, 49).

A second group of somatosensory pathways, referred to as indirect pathways, mediate arousal-affective aspects of somatic sensation (particularly pain) and visceral sensation Indirect pathways are important for the mechanism of pain and analgesia and visceral and sexual sensation. Included are the paleospinothalamic, spinoreticular, and spinomesenchepalic pathways, as well as the propriospinal multisynaptic system. Several spinal cord segments are connected by propriospinal neurons (14, 49).

The dorsal and ventral spinocerebellar tracts, the third group of somatosensory pathways, carry information for the unconscious control of posture and movement. These are two-neuron pathways that terminate in the ipsilateral cerebellum and do not relay in the thalamus (14, 49).

The direct somatosensory pathways are crucial to comprehending and diagnosing neurologic illness. Lesions at different levels of the neuroaxis disrupt sensory function in different ways; neurologic diseases can be localized by matching the patient's signs and symptoms with the anatomical distribution of these pathways. Disturbances of the peripheral nerves or spinal roots are segmentally distributed, frequently impact all sensory modalities, and may be related to the perception of pain. Lesions of the spinal cord can cause segmental sensory loss at the level of the lesion and variable sensory loss at all levels below the lesion. Lesions in the posterior fossa are associated with contralateral sensory loss over the trunk and limbs and ipsilateral sensory disruption in the face. Supratentorial lesions generate contralateral impairments in all senses. Due to the fact that each somatosensory pathway serves diverse roles, the loss of a certain sensory modality while preserving others permits the anatomical localisation of lesions in the nervous system. Lesions of the direct dorsal column pathway impact tactile discrimination, whereas lesions of the spinothalamic system primarily impact pain and temperature perception. Some somatosensory modalities, particularly touch, can still be sensed in circumstances of pathway interruption because of overlap or redundancy among parallel somatosensory pathways (14, 49).

2.4.2 Sensory of Fingertip

The processing of tactile sensory and visual input involves neural mechanisms that identify geometrical features of a stimulus, such as the shape and edge orientation. Feature extraction also begins very early in the tactile processing pathway, at the distal arborization of first-order tactile neurons. It has a branch of distal axon in the skin and form many transduction sites, give rise to complex receptive fields with many highly sensitive zones (50-54).

The fingertips are the most delicate body parts. They are densely consisting with thousands of nerve endings, which result in complex patterns of nerve impulses that convey the information about the texture, shape, and size of objects, and ability to analyze objects by touch and manipulate them depends on the continuous influx of this information (55, 56).

There are two main types of touch receptor organs in the nerve ends of the fingertips; Meissner corpuscle which is sensitive to fast deformation through the skin and Merkel discs which is slow deformation through the skin. Each nerve ending branch underneath the skin surface forms an elliptical receptive field with highly sensitive zones distributed within it (57).

The individual neurons signaled edge orientation both through the intensity and temporal structure of their response. An individual neuron habitually responded with higher peak firing rates for some edge orientations than others, it is because of a higher degree of spatial coincidence with highly sensitive zones. Given that the spatial zones of highly sensitive zones differ between neurons and overlapping receptive fields, neuron populations can provide strong information about edge orientation (58).

2.4.2.1 Two-point Discrimination (2PD)

Two-point discrimination is defined as the smallest separation between two stimulations placed on the skin that can be discriminated against as two separate points. This test originally regarded as an innervation density test of afferent fibers. 2PD testing has been found to be very helpful in the assessment of nerve injuries that is distributed to hand sensory. 2PD has been proved to be a valid measurement of

sensibility in the hand, especially in the fingertip area. Thus, 2PD is one of the most widely used tests which hand surgeons use to assess hand sensibility (59).

Many previous studies have used this assessment to measure sensory capacity in men and women, young and old, traumatic brain injury patients, lumbosacral radiculopathy problems, peripheral injury, and normal subjects. However, most 2PD studies have been conducted in peripheral injury patients or normal subjects, and some have focused on central nervous system disorders. Thus, it needs to be developed and it needs to be developed so that it can be a suitable examination for certain specific problems and specific purposes. 2PD is divided into two ways of measurement; static 2PD and moving 2PD (60).

2.4.2.1.1 Standardized Measurement of 2PD

2.4.2.1.1.1 Equipment

The examination of static and moving 2PD sensation perform using a standardized Dellon discriminator (Baseline Discrim-A-Gon Discriminator). The device is composed of two plastic discs, which has a series of metal pins separated by different distances (1 to 15 mm) (61).

2.4.2.1.1.2 Procedures

There are 2 types of 2PD measurements; static 2PD and moving 2PD (62, 63). Static 2PD starts with touch the participant's fingertips with one or two points randomly. Measure in one by one finger in 10 times test and increase or decrease the distance between the points. For the moving 2PD, perform the test like static 2PD but starts from proximal to distal on the volar distal phalanx of the fingertip.

2.5 Hand Function

Muscular strength is functionally highly important in daily life; therefore, this ability is usually assessed in rehabilitation (64). In the assessment of muscular strength especially for upper limb, grip strength and pinch strength are often examined because they have a good result that important and related to other abilities,

such as upper limb gross motor and fine motor (19). Hand motor is also really necessary as a benchmark of rehabilitation progress.

2.5.1 Grip Strength

Handgrip strength plays an important role in people's daily lives and serves as a reliable proxy indicator of the ability of an individual hand motor, such as holding objects, carrying out domestic tasks, and self-care activities (65). The weaker grip is associated with the prediction of morbidity, disability and mortality across populations of different ages, income levels and ethnicities, (66-72) as is decline in grip strength (73, 74). Adult risk factors, health condition, height and adiposity, cognition and health behaviors, have been associated with succeeding grip strength (75, 76), and with age-related decline (77-85). Developmental factors, such as physical growth, birth weight, cognitive and motor development and childhood socioeconomic conditions are also correlated to adult grip strength (86, 87). From the other previous study, low grip strength is also associated with poor nutritional status, low levels of fitness, and a range of adverse outcomes including increased functional limitations, disability, prolonged length of stay in hospitalized patients, as well as mortality (88). In the assessment of muscular strength especially for upper limb, grip strength is often examined because it has clinical results that can be a benchmark for the rehabilitation progression (19).

Normal values for grip strength in healthy subjects have been published, stratified by age and gender; for example, 29.7–37.7 kg for men and 22.3–23.8 kg for women who are seventy years old, and 19.4–30.6 kg for men and 16.3–17.7 kg for women in their eighties (64). Numerous factors, including height, weight, age, gender, hand posture during measurement, degeneration of sensory component, muscle mass, and other anthropometry conditions, influence grip strength. (89). Previous studies proved that grip strength correlates with the strength of the erector spine, quadriceps femoris, shoulder abductors, and total muscle strength (64). In a number of investigations, grip strength on the affected side of hemiparetic stroke patients was assessed and found to be related to bone density, muscle tone, muscular stiffness, and motor paresis. To compensate for function loss on the afflicted side, it

is crucial for patients with hemiparetic stroke to have strong muscles on the unaffected side (64).

2.5.1.1 Standardized Measurement of Grip Strength

2.5.1.1.1 Equipment

Grip strength measurement can assess in many ways. From many previous studies, the common tools used for grip strength measurement are Smedley-type dynamometer, computerized Grippit dynamometer, and biometric with Jamar model dynamometer (64, 90, 91). The most frequently used by some researchers is with the Jamar model dynamometer. The differences between these tools are, Smedley-type dynamometer use manual type, it doesn't need a connection with a computer. Besides, the Grippit dynamometer consists of a vertical cylinder on a foot and has a wireless computer connection. The common one, Jamar model is a different model with two others, hydraulic dynamometer gives accurate and repeatable grip strength readings. Features adjustable 5-position handle and reads kilos and pounds (90). In this investigation, the researcher opts for accurate measurement utilizing the *Camry* hand dynamometer

2.5.1.1.2 Procedures

A brief interview precedes all testing, to determine if subjects met the criteria. Grip strength measures with the participants seated with the forearm resting in a semi-pronated position with the shoulder abduction, the elbow flexion, and the wrist dorsiflexion. First, 2 trials with submaximal isometric contractions perform to familiarize the participant with the equipment. Test performs 3 times in the second handle position. The highest voluntary contraction record as the maximal grip strength (isometric). In previous test-retest reliability study, high Intra-class Correlation Coefficients (ICC2,1) were found for both the less affected and the more affected hand (0.95–0.96) with acceptable measurement errors (standard error of measurement, SEM%, 7.2–9.2%) in forty-five persons with mild-to-moderate paresis in the upper extremity (90).

2.5.1.1.3 Normative Data for Grip Strength

Study	Origin	Time/meantime ± SD	Measurement Tool	Sample Size	Age/Mean Age ± SD	Unit	Grip Strength Score	
							Less-aff	More-Aff
Bohannon (2004)	USA	Not stated	Jamar dynamometry	26	71.1 years ± 11.7	N	243,2 ± 98,0	70,5 ± 87,7
Harris et al. (2007)	Canada	5.1 years ± 4.1	Jamar dynamometry	93	50-93 years	Kg		13,0 ± 11,1
Nascimento (2012)	Brazil	10 years ± 4.9	HG dynamometer Jamar	12	32-67 years	Nm	33,0 ± 9,3	15,0 ± 10,4
Betrand et al. (2015)	Switzerland	Week 1	Jamar dynamometer	34	18 - 80 years	Kg		8,45 ± 10,60
		Week 2			18 - 80 years			10,92 ± 12,37
		Week 4			18 - 80 years			12,23 ± 12,24
		Week 8			18 - 80 years			13,92 ± 12,98
		Week 12			18 - 80 years			15,74 ± 14,22
Akinwande et al. (2015)	Nigeria	12-week	Handheld dynamometer (Haoyue, China)	32	65-84 years	Kg	21,9 ± 8,87	
Ekstrand et al. (2016)	Swedan	10-116 Month	Computerized dynamometer Grippit	45	44-76 years	N	351,5 ± 122,0	244,3 ± 113,9
Takahashi et al. (2017)	Japan	Not stated	Smedley-type dynamometer	31	73.6 ± 7.4 years	Kg	17,3 ± 6,5	
Yi et al. (2017)	Korea	First 2 month	Jamar hydraulic hand dynamometer	127	68.6 years ± 14.9	Kg		3,0 ± 6,8
Stock et al. (2019)	Norway	5 - 26 days	A Biometrics E-LINK EP9 evaluation system (Biometrics Ltd, Gwent, UK, 2006), with an electronic hand dynamometer (G100)	47	44-78 years	(N/s)	530 ± 196	204 ± 203
Pennati et al. (2020)	Swedan	2 Week - 6 Month	Jamar isometric dynamometer	80	52,7 years ± 9,4	Kg	35,3 ± 10,45	10,35 ± 13,86

Table 1. Grip strength score in stroke patients in earlier studies

This table shows about grip strength score in stroke patients from many previous studies with different criteria and different measurement tools. Basically, the grip strength score for healthy subjects and subjects with any problem is different, like in different sex subject. A healthy subject gets a score higher than the illness subject, and the male subject score is higher than female.

For score in men, a grip strength of 26–32 kg was classified as "intermediate" and less than 26 kg as "weak"; while >32 kg was classified as normal. In women, grip strength of 16–20 kg was categorized as "intermediate," less than 16 kg as "weak," and > 20 kg as "normal". This is a previous result that shows the different score in different sex and group of subjects (92).

A study in 2015 researched handgrip strength scores in elderly patients with chronic illness. They proved that a healthy subject (control group) and chronic illness subject (patients' group) had a different hand grip scores, and for the male and female

group also had a different score. For example, a male subject in the patients' group got scores 26,1 and 20,4 for females. In the control group, the male subject got to score 29,5 more than female 24,2. Besides, they also proved that different groups of illnesses had a different rate of the score. For musculoskeletal cases, the score is around 24,0. In a neuromuscular group, the score is around 21,9 and 22,5 for multimorbidity. The result shows that male had a higher handgrip strength score than female, healthy subject had a higher score than illness subject, and neuromuscular is a case which had the lowest score for handgrip strength (92).

2.5.2 Fugl-Meyer Assessment – Upper Extremity (FMA-UE)

The Fugl-Meyer Assessment (FMA) is one of the most used and recommended assessment scales of sensorimotor function in stroke in both the upper and lower extremities. The name of FMA is developed from the name of the developer, Fugl-Meyer. Fugl-Meyer et al. established the validity of this evaluation approach by visually illustrating the sequence of development of the successive phases of motor return for the arm and leg. Fugl-Meyer discovered a strong association (.76 to.98) between the motor score and the ability to perform activities of daily living (ADL), particularly in the upper extremities (93). The items of Fugl-Meyer motor assessment includes items dealing with the shoulder, elbow, forearm, wrist, and hand in the upper extremity and the hip, knee, and ankle in the lower extremity. The Fugl-Meyer assessment consists of 155 items, which is an impairment measure. In the Fugl-Meyer assessment, each item is graded on a three-point ordinal scale (2 points for details being performed completely, 1 point for details that performed partially, and 0 for details not being performed). The highest motor performance score on the Fugl-Meyer scale is 66 for the upper extremities, 34 for the lower extremities, 14 for balance, 24 for sensation, and 44 for passive joint motion and joint pain. Fugl-Meyer assigned motor function scores to items that assessed motor function alone, with a total possible score of 100 points (94). In this study, we focus on the Fugl-Meyer assessment for the motor in the upper extremity (FMA-UE). The scale contains 33 components, which are separated into 4 subscales: shoulder/elbow (A, 18 items), wrist (B, 5 items), hand (C, 7 items), and coordination/speed (D, 3 items). Intra- and inter-rater reliability of the FMA-UE, as measured by the intraclass correlation coefficient

(ICC), has been shown to be excellent, with values above 0.90 for both the total and subscale levels in the chronic and subacute phases. The FMA was confirmed as a gold standard assessment in post-stroke patients (95). In this study, FMA-UE was performed just to examine the participant's ability in the hand and wrist. Thus, the FMA-UE test for this study consists of 2 parts, B and C of Fugl-Meyer assessment – upper extremity with maximum score is 24.

2.5.2.1 Standardized Measurement of FMA-UE

2.5.2.1.1 Equipment

The outcome measures were both versions of the FMA (upper extremity - hand section [two-level ordinal scale, 12 items, 0–24 points] (96). Use the FMA-UE version and just assess the participant with the B and C part only because this measurement has proved its validity.

2.5.2.1.2 Procedures

The assessment took place in a quiet room. All examiners were physiotherapists with experience in the neurological field for at least one year (97). In this study, the examiner only needs the B and C part of the FMA-UE to examine the participant's hand function.

2.5.2.1.3 Normative Data for FMA-UE

In a previous study by Luft et al., in U.S subjectively categorized patients as severely impaired with an FMA-UE total score less than 25 and moderate impairment between 26-50 (98). In another study, Boissy et al., also in U.S, similarly subjectively divided stroke survivors into two FM-UE groups, with severe deficit defined by <44 and moderate-normal defined by scores > 44 (99). Even though previous study already proved FMA-UE part B and part C validity and reliability as “stand-alone” measurement with its concurrent validity and its inter-rater realiability (100), there is no cut-off point explained.

2.6 Relationship between Sensory and Motor System

Sensory inputs from Golgi tendon organs (GTO), joint proprioceptors, muscle spindles, and low-threshold mechanoreceptors are not only processed centrally for conscious sensation but are also essential for the unconscious adjustment of body posture and muscle tone, as well as for the continual monitoring of motor function. Inputs from muscles, skin and joint receptors provide continuous information about the condition, position, and movement of the body. All motor system components, including the cerebellum, brainstem, motor cortex, and motor neurons in the spinal cord, receive this information as feedback.

The primary source of somatosensory information that acts as feedback to the motor system is the GTO, muscle spindle, and low-threshold mechanoreceptors of the skin and tendons. The location of the low-threshold mechanoreceptors of the skin is in the fingertip. Thus, the fingertip is the most sensitive part of the body with the somatosensory inputs because of its thick neuron density.

The more crucial is the major afferent input to the ventral horn interneuronal pool. These interneurons integrate input from primary afferent, supraspinal circuits, and local circuits to regulate motor neuron activity for maintenance of muscle tone (degree of stiffness) and coordination of motor acts. (14).

Many previous studies proved the correlation between sensory and motor systems, and they showed about positive correlation. Anatomically, Secondary motor areas (SMA) and premotor areas (PM) respond to sensory inputs (21), and the primary motor cortex (MI) is not solely a motor structure. It is involved in the processing of somatosensation (101). So, when stimulation of cutaneous is given, muscle and joint afferents can drive neurons in the primary motor cortex (102). In sensory stimulation, different forms of stimulation are affected to facilitate motor behaviour (103). Also, there are other sensory modalities besides somatosensory, proprioceptive, and tactile relevant for motor and skill acquisition; vision, auditory, and vestibular systems (104). Correlation between both systems is also found in stroke patients. Cutaneous anesthesia of the intact hand of chronic stroke patients resulted in improvements during the execution of a vigorous finger motor activity with the paretic hand (13). In contrast, in individuals with acute and subacute hemiparesis, they discovered

moderate to significant associations between hand function and fine sensory testing (light touch and location of the thumb), but only a minor correlation in patients with chronic hemiparesis. (105).

CHAPTER III

MATERIAL AND METHOD

3.1 Research Design

The current study is a cross-sectional study with an observational research method. The individuals after stroke were recruited in the study to explore 1) the association of the 2PD and grip strength and 2) the association between grip strength and FMA-UE.

3.2 Participants Characteristics

A convenient sample of 41 stroke patients was drawn from clinics or hospitals in Bangkok, Thailand.

3.2.1 Inclusion Criteria

- 3-12-months post-stroke
- Ability to move hand/finger (able to grip handheld tool on the second position of the hand strength tool)
- Male and female
- Age more than 40 years old
- First stroke leading to upper limb paresis
- Ability to understand simple commands (no receptive aphasia)
- Ability to provide informed consent

3.2.2 Exclusion Criteria

- Having peripheral injury history
- Having other neurological conditions (e.g Parkinson disease)
- Having a peripheral neuropathy history
- Having a severe cognitive impairment

3.3 Sample Size

The sample size was calculated from the following equation

$$n = \left[\frac{\left(Z_{1\frac{\propto}{L}} + Z_{1-\beta}\right)}{C}\right]^2 + 3$$

$$C = 0.5 \text{ x } \ln\left[\frac{(1+r)}{(1-r)}\right]$$

n = Sample size

$Z_{1\frac{\propto}{L}}$ = Z-value when the level of confidence is set at 95% (= 1.96)

$Z_{1-\beta}$ = Z-value when the level of Power is set at 80% (= 0.84)

r = Expected correlation coefficient from the previous study (106) = 0.43

$$C = 0.5 \text{ x } \ln\left[\frac{(1+0.43)}{(1-0.43)}\right]$$

$$= 0.46$$

$$n = \left[\frac{(1.96+0.84)}{0.46}\right]^2 + 3$$

$$= [37.05] + 3$$

$$= 40.05 \sim 41 \text{ participants}$$

So, the minimum sample size needed = 41

3.4 Research Administration

Within consent to take part in this study was obtained from all participants who met the inclusion and exclusion criteria before the commencement of data collection. In the first part, participants were asked to answer a screening questionnaire, history taking, and provide informed consent.

In this study, the screening questionnaire part was completed with an additional test for the dominant hand. Dominant hand test assessed by Edinburgh handedness inventory.

The participants who were included in this study were assessed for sensory of fingertips by 2PD and for hand function by grip strength and FMA-UE hand. These assessments were applied in order. The steps to assess all these assessments are,

3.4.1 Two-point Discrimination

In this study, the researcher performed the 2PD test in 2 methods. The first one was in static 2PD and the second one in the moving 2PD. These are 10 steps in each category for doing the 2PD measurement;

a) Static 2PD

1. The participant was in a seated position on the chair with the foot plantar fully on the floor and the forearm resting in a semi-pronation position on the table (adjust the chair until the elbow on the table at 90° flexion with the shoulder at 30° abduction and wrist fully open). If the participant cannot sit stable, just support the unstable or weak body parts with a towel until he or she feels comfortable and stable.
2. The participant was informed about the measurement clearly until they understood what he or she should do next.
3. The participant was informed to respond to the stimulation from the test by saying "one point" or "two-point" with vision occluded.
4. The examiner cleaned the participant's skin surface on each fingertip with an alcohol swab just to make sure that there was nothing other sense.

5. The participant was asked to close their eyes. The examiner was ready for a face shield that has been blocked with a piece of paper. Asked the participant to close his/her eyes and use the face shield to block the vision.
6. The examiner began to measure at 5 mm. Touch the participant's fingertip with one or two points, apply it randomly but assess one by one finger from the first finger. For each finger, the examiner tested ten times or ten stimulations.
7. The examiner applied the force of the touch pressure only to the point of blanching in a longitudinal direction to avoid crossing digital nerve innervation in the finger perpendicular to the skin.
8. The examiner increased or decreased the distance between the two points. If the participant is unable to discriminate two points correctly at 5 mm, increase the distance between the points. If the participant can discriminate two points correctly at 5 mm, decrease the distance, and continue until the examiner find the smallest distance the participant discriminates as two points.
9. After the examiner completely examined, the examiner records the overall participant's result. Seven correct responses out of ten in one area were required for a correct response (63).
10. The tests were performed for about 8-12 minutes for each hand.

b) Moving 2PD

1. The participant was in a seated position on the chair with the foot plantar fully on the floor and the forearm resting in a semi-pronation position on the table (adjust the chair until the elbow on the table at 90° flexion with the shoulder at 30° abduction and wrist fully open). If the participant cannot sit stable, just support the unstable or weak body parts with a towel until he or she feels comfortable and stable.
2. Participants are informed about the measurement clearly until they understand what he or she should do next.
3. The participant was informed to respond to the stimulation from the test by saying "one point" or "two-point" with vision occluded.
4. The examiner cleaned the participant's skin surface on each fingertip with an alcohol swab just to make sure that there was nothing other sense.

5. The participant was asked to close their eyes. The examiner was ready for a face shield that has been blocked with a piece of paper. Ask the participants to close their eyes and use the face shield to block their vision.
6. The examiner performed the test from proximal to distal on the volar distal phalanx of the fingertip. The points are longitudinal to the axis of the finger and are placed perpendicular to the skin. Move the points along the fingertip only, from proximal to distal.
7. The examiner began the test with a distance of 5 to 8 mm and increased or decreased as needed.
8. The examiner lifted the points off the tip of the finger. Do not allow the points to come off the tip of the finger separately because this gives the subject information that it was two points. For each finger, the examiner has tested ten times or ten stimulations.
9. After the examiner completely examined, the overall participant's result was recorded. Seven out of ten correct responses in one area are required for a correct response.
10. The tests were performed for about 8-12 minutes for each hand.

3.4.2 Grip Strength

The steps to use this tool:

1. The participant was in a seated position on the chair with the foot plantar fully on the floor and the forearm resting in a semi-pronated position on the table (adjust the chair until the elbow on the table at 90° flexion with the shoulder at 30° abduction and wrist fully open). If a participant

cannot sit stable, just support the unstable or weak body parts with a towel until he or she feels comfortable and stable.

2. Participants were informed about the measurement clearly until they understood what they should do next.
3. The examiner cleaned the participant's hand palmar with an alcohol swab just to make sure that there was nothing other sense.
4. The examiner calibrated a dynamometer to the "2" level for all participants' examinations as the standard position presented by previous study referring to the initial grip position for vigorous gripping (107). This item's default value in the computer is 2.
5. The examiner gave the information to the participant to not allow the participant to fully squeeze the dynamometer before testing. Just ask the participant to try a little squeeze for short twice to make the participants familiar with the tool.
6. In the real testing, the examiner must coach the participant by saying "squeeze, squeeze, squeeze" while the participant was squeezing.
7. The examiner gave information about stopping when the examiner sees the value/score of the squeezing starting to go down.
8. Perform the test 3 times with 30 s rest between the trials and calculate the average score.
9. After the examiner completely examined, the overall participant's result was recorded.
10. The tests were performed for about 5-10 minutes for each hand.

3.4.3 Fugl Meyer Assessment – Upper Extremity Hand

The examiners are accustomed to FMA-UE hand by reading the scoring sheet and manual and finally assessing partcipants.

1. The examiner prepared a pen, stopwatch, manual, and scoring sheet for the test.
2. The examiner began with a good conversation with the participant to make sure that the participant was in full consciousness.

3. Participants were informed about the measurement until they understood what he or she should do next. The examiner gave an example of each instruction.
4. The examiner asked the participant to carry out the instructions that the examiner asked.
5. The FMA-UE test for this study consists of 1 part, only part B and part C of the Fugl-Meyer assessment – upper extremity. The test performed once time each point with 10 seconds of rest.
6. This test requires no more than 8 to 10 minutes to administer.

(Manual and scoring sheet in Appendix C)

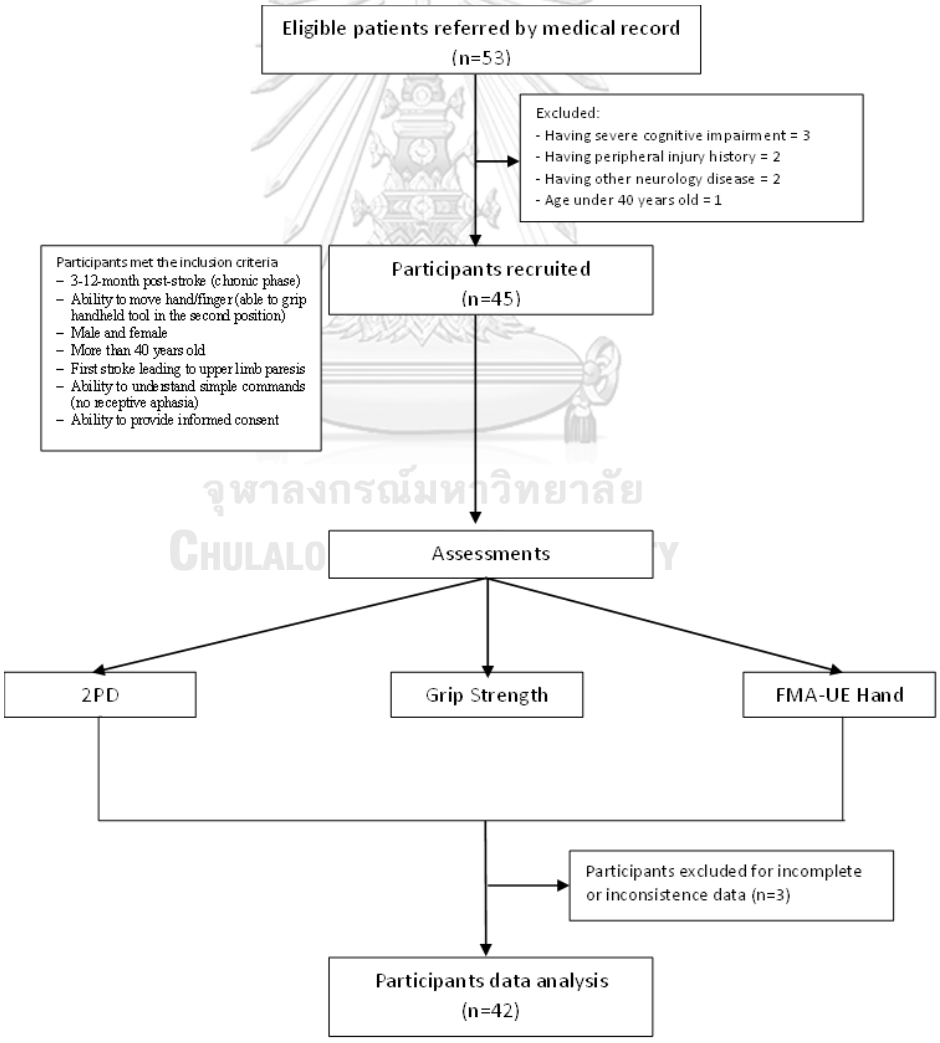

Figure 3. Research Administration

3.5 Outcome Measurement

3.5.1 Dependent Variable

The hand Function of the participants was evaluated by FMA-UE Hand as the dependent variable of this study.

3.5.2 Independent Variables

The independent variables were evaluated by 2PD and Grip Strength

3.5.3 Confounding Variables

Age, cognition, gender, and BMI are classified as confounding factors

3.6 Statistical Analysis

All Statistical analyses were performed using SPSS software (IBM SPSS Statistics for Windows, Version 22). The statistical significance level was set at 0.05 for all analyses. Normality test using the Saphiro-Wilk test. Demographic data were reported with descriptive statistics. The result was not normally distributed. Spearman's rank correlation coefficients were selected.

3.7 Ethical Consideration

The study results are presented in terms of quantitative value. All participant information kept private and will not be released, and any participant may withdraw from the study at any moment without incurring any penalty. Moreover, the study was approved by the Ethics Review Committee for Research Involving Human Projects, Chulalongkorn University (COA No.251/2020), and the National Brain Hospital of Indonesia (No. LB.02.01/KEP/072/2021).

3.8 How to Protect Welfare and Safety of Participants Including Risk Management

Grip strength and 2PD measurement do not have crucial risks, but if participants repeat it many times with maximum force, it will cause exhaustion. This is closely related to the appropriate parameter, lack of calibration of the device, and lack of

communication between investigator and participant. In this study, the investigator will be concerned about how participants receive the instructions, the parameter for treatment, and calibrated before starting. Moreover, during treatment investigator will ask about the feeling of the participants. Information of participants in this study will be kept confidential. However, the presentation of these results will be presented the whole data of the information without full identity. Thus, the information cannot identify each of the participants. When the research has been finished, all data of participants will be destroyed within one year.

3.9 Research Limitation

This research did not use laboratory assessment tools which has high validity and as the gold standard. This research only used clinical assessment with good reliability and validity. Thus, later the result of this research will need to compare with other methods which use gold standard assessment tools in the laboratory, especially for sensory test.

3.10 Budget

Table 3 Budget

No	Items	Baht
1. Expense during the process of data collection		
1.1	Data collection fee for participants (41 participants * 250baht)	10,250
1.2	Payment for 1 research assistant (500baht/day * 30 days)	15,000
1.3	Research permit for clinic	5,000
2. The expense of equipment and documents		
2.1	Cost for documents (questionnaires, data collecting sheets)	4,000
2.2	Dellon Discriminator (2PD Equipment)	2,000
2.3	Grip dynamometer equipment maintenance	1,000
3. Traveling expenditures for researcher and assistant (500 * 25 days)		12,500
4. Costs of telephone calls for general arrangements and communication		2,000
5. Miscellaneous expenditures (postal costs, drinking water for participants, basic emergency medical kits)		3,000
TOTAL		**54,750**

CHAPTER IV

RESULTS

4.1 Participants Characteristics

Forty-two participants aged 40-79 years (64% of them are males and only two left-handed dominants) with stroke participated. All participants had a single stroke attack (57% left-side brain lesion), with 43% having a diabetic history and 69% participants having a normal BMI (Table 1). According to the approval and declaration of the Ethics Committee of Chulalongkorn University, and the National Brain Center Hospital of Indonesia, participants provided written informed consent for each trial. Patients were assessed no later than three months following stroke and no more than one year after stroke onset. From the medical history of participants, all subjects had a normal peripheral nerve function with no previous injury or compression syndrome.

Table 4. Distribution of age, sex, diabetic history, dominant hand, brain lesion, and BMI of the participants

	Intervals	Frequency	Percentage
Middle-aged Adults	**40 – 49**	**7**	**17%**
	50 – 59	**18**	**43%**
Old Adults	**60 – 69**	**13**	**31%**
	70 - 79	**4**	**10%**
Male		**27**	**64%**
Female		**15**	**36%**
Have A History of Diabetes		**18**	**43%**
Have No History of Diabetes		**24**	**57%**
Right-handed Dominant		**40**	**95%**
Left-handed Dominant		**2**	**5%**
Right Brain Lesion		**18**	**43%**
Left Brain Lesion		**24**	**57%**

Underweight (BMI)	**<23**	**9**	**21%**
Normal (BMI)	**23-30**	**29**	**59%**
Overweight (BMI)	**>31**	**4**	**10%**

From the result of participants examination by MRI, the highest incidence of the lesion location is in left corona radiata (Table 5).

Table 5. Distribution of lesion location of participants

Lession Location	Participants	Percentage
Right thalamus	1	2%
Right lateral periventricular	2	5%
Right corona radiata	3	7%
Right external capsule	2	5%
Right pons	2	5%
Right basal ganglia	2	5%
Right frontal lobe	2	5%
Right internal capsule	1	2%
Right frontotemporoparietal	1	2%
Right cerebellum	1	2%
Right corona radiata and basal ganglia.	1	2%
Left temporooccipital lobe	2	5%
Left internal capsule	3	7%
Left frontal lobe	3	7%
Left corona radiata	4	10%
Left lenticular nucleus	1	2%
Left lateral ventricle	1	2%
Left-sided mesencephalon	1	2%
Left parietal lobe	1	2%
Left basal ganglia	2	5%
Left Thalamus	1	2%
Left frontal and left parietal lobes	1	2%
Left frontal lobe and corona radiata	1	2%
Right temporoparietal and left frontotemproparietal lobes	1	2%
Right frontal lobe, left external capsule	1	2%
Right and left lateral periventricular.	1	2%
Mild brain atrophy	2	5%
No abnormalities	2	5%

Table 6. FMA-UE Hand Score

Score	Participants	Percentage
24	25	60%
23	10	24%
22	1	2%
19	1	2%
18	1	2%
15	1	2%
14	1	2%
10	1	2%
4	1	2%

From the result of participants grip strength assessment, the score that above 21 (92) kg was only 6 participants, the rest (36 participants) was under 21kg.

4.2 Correlation between FMA and grip strength, FMA and static 2PD, FMA and moving 2PD, grip strength and static 2PD, grip strength and moving 2PD

The table shows the correlation between each group on the paretic side. The FMA has a high positive correlation with the grip strength test. Both assessments of the 2PD test have a negligible correlation with FMA and grip strength.

Table 7. Correlation between each group on the paretic side *(p-value: <0.05)*

	FMA – Grip Strength	FMA – Static 2PD	FMA – Moving 2PD	Grip Strength – Static 2PD	Grip Strength – Moving 2PD
Spearman's rho	**.706**	**.005**	**.011**	**-.128**	**-.090**
Sig. (2-tailed)	**<.001**	**.992**	**.768**	**.875**	**.794**

4.3 Comparison between static and moving 2PD in paretic and non-paretic hand

The moving 2PD was significantly different from static 2PD (Table 8). It shows both static and moving 2PD have better score in non-paretic hand and moving 2PD has better than static 2PD.

Table 8. Mean score of static and moving 2PD in paretic and non-paretic hand

	Paretic Hand Mean (SD)	Non-Paretic Hand Mean (SD)
Static 2PD	5.6095 (1.39403)	5.4190 (1.36350)
Moving 2PD	4.8571 (1.23863)	4.7310 (1.23863)

Mean score of threshold discrimination in different finger is variative. See from Table 9 and 10, as in the table 8, these table also shows that the results are better in the non-paretic hand. From different finger, the second finger is the more sensitive finger for threshold discrimination.

Table 9. Mean score of threshold discrimination in different fingers (Paretic Hand)

Paretic Hand									
Static 2PD					Moving 2PD				
Finger 1	Finger 2	Finger 3	Finger 4	Finger 5	Finger 1	Finger 2	Finger 3	Finger 4	Finger 5
5.33	5.21	5.59	5.74	6.17	4.71	4.4	4.76	5.11	5.28

Table 10. Mean score of threshold discrimination in the different fingers (Non-paretic Hand)

Non-paretic Hand									
Static 2PD					Moving 2PD				
Finger 1	Finger 2	Finger 3	Finger 4	Finger 5	Finger 1	Finger 2	Finger 3	Finger 4	Finger 5
5.14	5.05	5.4	5.52	5.98	4.55	4.05	4.38	4.93	5.09

The score in table 11 and 12 show the mean score of total correct responses in the different fingers. Both static and moving types in paretic and non-paretic hand, the fifth finger shows the result lower than other fingers.

Table 11. Mean score of correct responses in the different fingers (Paretic Hand)

Paretic Hand									
Static 2PD					Moving 2PD				
Finger 1	Finger 2	Finger 3	Finger 4	Finger 5	Finger 1	Finger 2	Finger 3	Finger 4	Finger 5
8.09	7.95	8.14	7.74	7.62	8.19	8.09	7.95	7.83	7.66

Table 12. Mean score of correct responses in the different fingers (Non-paretic Hand)

Non-paretic Hand									
Static 2PD					Moving 2PD				
Finger 1	Finger 2	Finger 3	Finger 4	Finger 5	Finger 1	Finger 2	Finger 3	Finger 4	Finger 5
8.14	8.33	8	7.81	7.76	8.40	8.33	7.98	8.14	7.88

CHAPTER V

DISCUSSION

This study aims to observe the association between sensory of the fingertip, hand motor, and hand function in chronic stroke patients. The participants had no experience with hand peripheral nerve injury. As described in previous research, the researchers proved the correlation between sensory and motor systems, showing a positive correlation. Anatomical function, secondary motor areas (SMA) and premotor areas (PM) respond to sensory inputs (21), and the primary motor cortex (MI) is not solely as a motor structure. It is involved in the processing of somatosensation (101). So, when cutaneous stimulation is given, muscle and joint afferents can drive neurons in the primary motor cortex (102). In sensory stimulation, different forms of stimulation are affected to facilitate motor behaviour (103). Also, other sensory modalities besides somatosensory, proprioceptive, and tactile are relevant for motor and skill acquisition; vision, auditory, and vestibular systems (104). Correlation between both sensory and motor systems also found in stroke patients. Cutaneous anesthesia of the intact hand of chronic stroke patients improved the performance of a dynamic finger motor task with the paretic hand (13). On the other hand, moderate to high associations were observed between fine sensory testing and hand function (light touch and positioning of the thumb) in acute and subacute stroke patients. However, they found only a weak correlation in patients with chronic hemiparesis (105).

5.1 Subject Characteristics

In age interval groups, the highest percentage was participants in the age group 50–59-year-old, around 43%, and the least percentage is around 10% for the 70–79-year-old group. Many previous studies showed the higher the age group, the higher the incidence of stroke (108-110). However, the number only shows the incidence of stroke without any information that the age group had a stroke for the first attack or the umpteenth attack. The result showed that the proportion of males is larger than the females. It is in line with a previous study that proved that stroke is more

common in males than females (111). The other result of participants was more than 50 percent of participants had left brain lesions, normal BMI, and no diabetes history.

5.2 Correlation between FMA and grip strength, FMA and static 2PD, FMA and moving 2PD, grip strength and static 2PD, grip strength and moving 2PD

In this study, grip strength and FMA-UE hand were significantly correlated. Adapted from Dancey and Reidy in 2004, the result was a "very strong correlation" because the score is more than 0.7 (0.706). The result are supported by previous study that stated maximal voluntary grip force were associated with motor and functional upper limb performance in chronic stroke subjects (112). Thus, recovery of recordable grip strength was reported to be one of the most sensitive indicators of initial upper limb(113), recovery in acute stroke patients and a reliable predictor of later functional recovery (114). It has also been proposed that grip strength assessments are the best way to identify upper limb motor deficits in stroke patients (115). The result of the study concludes that grip strength assessment is not only good for acute stroke but also for chronic stroke. Thus, grip strength assessment can be measured in the early phase and evaluated for each period to see the patient's motor and functional improvement.

This study also explored the correlation between hand sensory with hand motor and hand sensory with hand function. Researchers have previously discovered moderate to high correlation between hand function and fine sensory in acute and subacute stroke patients. However, they found only a weak correlation in patients with chronic hemiparesis (116). Also, different forms of somatosensory stimulation have facilitated motor behavior (117). In our assessment for sensory, motor, and function with 2PD, grip strength, and FMA-UE Hand, we found no correlation between 2PD with grip strength and 2PD with FMA-UE Hand. These findings could be due to 2PD many reasons. Such as, different sensory modalities are coded in various reference frames on the sensory side. To produce the desired movements on

the motor side, the positions of the sensory impulses must finally be converted into the natural coordinates of the muscles (118). Based on that, it might be more leverage if it involves multiple sensory sources. From another previous study, in the nerve repair cases, 2PD poorly tracks recovery of function following nerve injury and repair (119, 120). On the other hand, motor control theory explained that the individual, the task, and the environment interact to produce movement so this sensory assessment needs to be supplemented by other supporting examinations (121). On the other hand, previous research has indicated that somatosensory function is important for recovery of precision grip force control after stroke, and the neurobiological processes involving residual CST (corticospinal tract) integrity are important for rehabilitation of fine motor control of fingers after stroke (122).

5.3 Comparisons between static and moving 2PD in paretic and non-paretic hand

Another result of this study from 2PD tests which divided into static 2PD and moving 2PD. Static 2PD correlated with the patient's ability to perform tasks requiring precision sensory grip and moving two-point discrimination was found to correlate with the ability to identify objects (tactile gnosis). Static two-point discrimination encoding by *Merkel cell-neurite* mechanoreceptors which is respond to the small impression of the skin but are *slowly* adapting. While moving two-point discrimination encoding by *Meissner* and Pacinian corpuscle mechanoreceptors which are *Pacinian corpuscle* and *Meissner* are extremely rapidly adapting. Both have difference characteristic which is the results are not exactly the same (123). The results shows that there is difference threshold discrimination between static and moving two-point discrimination. It shows in moving two-point discrimination has smaller threshold than in static two-point discrimination (Table 8). It means that participants with post stroke detect moving two-point-discrimination more detail.

The Table 9 and Table 10 show that the second finger has the lowest mean score of threshold discrimination. It means that this area is the more sensitive area to sensing the lowest distance between two points in a fingertip called threshold discrimination. This result supported by previous study in 2020 which proved that in spontaneous softness discrimination, individuals explored the offered stimuli most

frequently using combinations of their index, middle, and, to a lesser extent, ring fingers. A common behaviour was to alternate between indenting with one finger and many fingers. Preferred fingers were the first or index finger, then the second or middle finger, then fourth or ring finger. Little finger and thumb were utilized least habitually (124).

The prior studies also support the results from Table 11 and 12 which show mean score of total correct responses in different fingers. The fifth finger or little finger had the lowest score about total correct response. Several reasons that might support this result, including analysis of fingertip width showed some similarities to the performance outcome. The index and middle fingers were broader than the ring finger, and the little finger was the smallest. When investigating compliant items, they employed finger width as a gauge for contact area, which is known to be crucial (123). It is also in line with earlier study about sensitivity of the fingertip also discussed with the number of mechanoreceptors in the fingertip that come into contact with an object during exploration. The other reason discussed from previous study is they found that the finger two and finger three are the more sensitive to softness than the finger four, and the finger five is least sensitive (124).

CHAPTER VI

CONCLUSION

Findings highlight a significant correlation between grip strength and FMA-UE Hand, but there is no correlation between 2PD and grip strength also 2PD and FMA-UE Hand in stroke patients. Also moving 2PD detect smaller distance in two-point discrimination test better compared to static 2PD. This may help guide health professionals especially physiotherapy during the rehabilitation phase, focusing on hand motor and function. Further research may need to consider residual CST (corticospinal tract) to see more results on correlation between 2PD with FMA-UE Hand and 2PD with grip strength.

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APPENDIX

Appendix A Measurement Tools

1. 2PD
    - Discrim-A-Gon Discriminator tool

2. Grip strength
    - Camry hand dynamometer

3. FMA-UE

FUGL-MEYER ASSESSMENT ID:

UPPER EXTREMITY (FMA-UE) **Date:**

Assessment of sensorimotor function **Examiner**:

Fugl-Meyer AR, Jaasko L, Leyman I, Olsson S, Steglind S: The post-stroke hemiplegic patient. A method for evaluation of physical performance. Scand J Rehabil Med 1975, 7:13-31.

B. WRIST support may be provided at the elbow to take or hold the starting position, no support at wrist, check the passive range of motion prior testing		**none**	**partial**	**full**
Stability at 15° dorsiflexion elbow at 90°, forearm pronated shoulder at 0°	less than 15° active dorsiflexion dorsiflexion 15°, no resistance tolerated maintains dorsiflexion against resistance	0	1	2
Repeated dorsifexion / volar flexion elbow at 90°, forearm pronated shoulder at 0°, slight finger flexion	cannot perform volitionally limited active range of motion full active range of motion, smoothly	0	1	2
Stability at 15° dorsiflexion elbow at 0°, forearm pronated slight shoulder flexion/abduction	less than 15° active dorsiflexion dorsiflexion 15°, no resistance tolerated maintains dorsiflexion against resistance	0	1	2
Repeated dorsifexion / volar flexion elbow at 0°, forearm pronated slight shoulder flexion/abduction	cannot perform volitionally limited active range of motion full active range of motion, smoothly	0	1	2
Circumduction elbow at 90°, forearm pronated shoulder at 0°	cannot perform volitionally jerky movement or incomplete complete and smooth circumduction	0	1	2
	Total B (max 10)			

C. HAND support may be provided at the elbow to keep 90° flexion, no support at the wrist, compare with unaffected hand, the objects are interposed, active grasp		**none**	**partial**	**full**
Mass flexion from full active or passive extension		0	1	2
Mass extension from full active or passive flexion		0	1	2
GRASP				
a. Hook grasp flexion in PIP and DIP (digits II-V), extension in MCP II-V	cannot be performed can hold position but weak maintains position against resistance	0	1	2
b. Thumb adduction 1-st CMC, MCP, IP at 0°, scrap of paper between thumb and 2-nd MCP joint	cannot be performed can hold paper but not against tug can hold paper against a tug	0	1	2
c. Pincer grasp, opposition pulpa of the thumb against the pulpa of 2-nd finger, pencil, tug upward	cannot be performed can hold pencil but not against tug can hold pencil against a tug	0	1	2
d. Cylinder grasp cylinder shaped object (small can) tug upward, opposition of thumb and fingers	cannot be performed can hold cylinder but not against tug can hold cylinder against a tug	0	1	2
e. Spherical grasp fingers in abduction/flexion, thumb opposed, tennis ball, tug away	cannot be performed can hold ball but not against tug can hold ball against a tug	0	1	2
	Total C (max 14)			

B. WRIST	/10
C. HAND	/14
TOTAL B-C	/24

Appendix B Personal Data Collection

PERSONAL DATA COLLECTION

ID:
Date:

Please answer the following questions by checking the correct box or fill the blank

1. Date of birth (Age) :

2. Gender :
   ☐ Female ☐ Male

3. Height :

4. Weight :

5. Body Mass Index (BMI) :

6. First Stroke : ☐ Yes ☐ No

   Date of stroke onset :

7. Having peripheral injury history :
   ☐ Yes ☐ No

8. Having diabetic history :
   ☐ Yes ☐ No

9. Additional Information (CT-Scan/Lab)
   -
   -
   -
   -

10. Dominant Hand : (Additional Information: Edinburgh Handedness Inventory)
    ☐ Right ☐ Left

11. Brain Lesion Side :

☐ Right ☐ Left

12. Paresis Side :

☐ Right ☐ Left

Table 1. Grip Strength Score Record

1. Right Hand

Grip Strength Score (kg)	Trials			
	1	2	3	Average

2. Left Hand

Grip Strength Score (kg)	Trials			
	1	2	3	Average

Table 2. Two-point Discrimination Score

1. Static 2PD

		Trials										**Correct Answer**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Finger 1	Distance											
	T/F											
Finger 2	Distance											
	T/F											
Finger 3	Distance											
	T/F											
Finger 4	Distance											

	T/F											
Finger 5	Distance											
	T/F											

2. Moving 2PD

		Trials										**Correct Answer**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Finger 1	Distance											
	T/F											
Finger 2	Distance											
	T/F											
Finger 3	Distance											
	T/F											
Finger 4	Distance											
	T/F											
Finger 5	Distance											
	T/F											

Appendix C Leaflet

ภาควิชากายภาพบำบัด คณะสหเวชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
Department of Physical Therapy,
Faculty of Allied Health Science, Chulalongkorn University

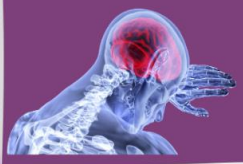
ความสัมพันธ์ระหว่างการรับสัมผัสปลายนิ้วและการทำงานของมือในที่ผู้ป่วยโรคหลอดเลือดสมอง

รายละเอียดโครงการวิจัย

งานวิจัยนี้ศึกษาเกี่ยวกับการประเมินความสามารถในการรับรู้ด้วยปลายนิ้วโดยการแยกแยะสองจุดและการควบคุมมือโดยการวัดแรงบีบมือ ผลจากการศึกษาในครั้งนี้จะทำให้ทราบข้อมูลเกี่ยวกับความสัมพันธ์ระหว่างการรับรู้กับการควบคุม ซึ่งจะเป็นประโยชน์ต่อนักกายภาพบำบัดที่ทำให้ทราบปัญหาที่เฉพาะเจาะจงมากขึ้นและสามารถเลือกแนวทางการรักษาที่ดีที่สุดสำหรับผู้ป่วยได้

คุณสมบัติผู้เข้าร่วม

- ชายหรือหญิง อายุมากกว่า 40 ปี
- อยู่ในช่วง 3-12 เดือน หลังเกิดภาวะโรคหลอดเลือดสมอง (FIRST ATTACK)
- มีความสามารถในการขยับมือ / นิ้วมือ
- สามารถสื่อสาร-เข้าใจคำสั่งได้



เชิญเข้าร่วมโครงการวิจัย

ขั้นตอนการมีส่วนร่วมในการวิจัย

1.ติดต่อผู้วิจัยทางโทรศัพท์ ไลน์ หรือ อีเมลล์
2.ท่านจะได้รับรายละเอียดของงานวิจัย
3.ทำแบบคัดกรองเพื่อเข้าร่วมงานวิจัย
4. เมื่อท่านผ่านเกณฑ์การคัดกรอง ท่านจะได้เข้าร่วมการวิจัยเป็นลำดับต่อไป

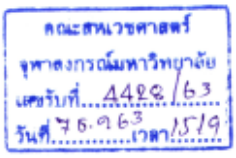
สอบถามข้อมูลเพิ่มเติม

- ผู้ช่วยศาสตราจารย์ ดร.อัญชลี ฝูงชมเชย/Orisa Elfath
- Email: elfathorisa@gmail.com
- โทร: 0896842535

*** หมายเหตุ: เมื่อสิ้นสุดการศึกษานี้ผู้เข้าร่วมจะได้รับค่าเดินทาง 200 บาท

Appendix D Ethic Approval

1. Ethic committee of Chulalongkorn University



บันทึกข้อความ

ส่วนงาน คณะกรรมการพิจารณาจริยธรรมการวิจัยในคน กลุ่มสหสถาบัน ชุดที่ 1 โทร.0-2218-3049
ที่ จว 307 /2563 **วันที่** 1 มิถุนายน 2563
เรื่อง แจ้งผลผ่านการพิจารณาจริยธรรมการวิจัย

เรียน คณบดีคณะสหเวชศาสตร์

สิ่งที่ส่งมาด้วย เอกสารแจ้งผ่านการรับรองผลการพิจารณา

ตามที่นิสิต/บุคลากรในสังกัดของท่านได้เสนอโครงการวิจัยเพื่อขอรับการพิจารณาจริยธรรมการวิจัย จากคณะกรรมการพิจารณาจริยธรรมการวิจัยในคน กลุ่มสหสถาบัน ชุดที่ 1 จุฬาลงกรณ์มหาวิทยาลัย นั้น ในการนี้ กรรมการผู้ทบทวนหลักได้เห็นสมควรให้ผ่านการพิจารณาจริยธรรมการวิจัยได้ ดังนี้

โครงการวิจัยที่ 164.1/63 เรื่อง **ความสัมพันธ์ระหว่างการรับสัมผัสปลายนิ้วและการทำงานของมือในบุคคลที่มีโรคหลอดเลือดสมอง** (ASSOCIATION BETWEEN SENSORY OF FINGERTIP AND HAND FUNCTION IN INDIVIDUALS WITH STROKE) ของ Orisa Elfath นิสิตระดับมหาบัณฑิต คณะสหเวชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

จึงเรียนมาเพื่อโปรดทราบ

(ผู้ช่วยศาสตราจารย์ ดร.ระวีนันท์ มิ่งภัคนีย์)
กรรมการและเลขานุการ
คณะกรรมการพิจารณาจริยธรรมการวิจัยในคน
กลุ่มสหสถาบัน ชุดที่ 1 จุฬาลงกรณ์มหาวิทยาลัย

AF 02-12

The Research Ethics Review Committee for Research Involving Human Research Participants, Group I, Chulalongkorn University
Jamjuree 1 Building, 2nd Floor, Phyathai Rd., Patumwan district, Bangkok 10330, Thailand,
Tel: 0-2218-3202, 0-2218-3049 E-mail: eccu@chula.ac.th

COA No. 251/2020

Certificate of Approval

Study Title No. 164.1/63 : ASSOCIATION BETWEEN SENSORY OF FINGERTIP AND HAND FUNCTION IN INDIVIDUALS WITH STROKE

Principal Investigator : MISS ORISA ELFATH

Place of Proposed Study/Institution : Faculty of Allied Health Sciences, Chulalongkorn University

The Research Ethics Review Committee for Research Involving Human Research Participants, Group I, Chulalongkorn University, Thailand, has approved constituted in accordance with Belmont Report 1979, Declaration of Helsinki 2013, Council for International Organizations of Medical Sciences (CIOM) 2016, Standards of Research Ethics Committee (SREC) 2017, and National Policy and guidelines for Human Research 2015.

Signature: Prida Tasanapradit
(Associate Prof. Prida Tasanapradit, M.D.)
Chairman

Signature: Raveenan Mingpakanee
(Assistant Prof. Raveenan Mingpakanee, Ph.D.)
Secretary

Date of Approval : 16 November 2020 Approval Expire date : 15 November 2021

The approval documents including;

1) Research proposal
2) Participant Information Sheet and Consent Form
3) Researcher
4) Questionnaires
5) Advertising leaflet

164.1/63
Date of Approval 16 NOV 2020
Approval Expire Date 15 NOV 2021

The approved investigator must comply with the following conditions:

1. *It's unethical to collect data of research participants before the project has been approved by the committee.*
2. *The research/project activities must end on the approval expired date. To renew the approval, it can be applied one month prior to the expired date with submission of progress report.*
3. *Strictly conduct the research/project activities as written in the proposal.*
4. *Using only the documents that bearing the RECCU's seal of approval: research tools, information sheet, consent form, invitation letter for research participation (if applicable).*
5. *Report to the RECCU for any serious adverse events within 5 working days.*
6. *Report to the RECCU for any amendment of the research project prior to conduct the research activities.*
7. *Report to the RECCU for termination of the research project within 2 weeks with reasons.*
8. *Final report (AF 01-15) and abstract is required for a one year (or less) research/project and report within 30 days after the completion of the research/project.*
9. *Research project with several phases; approval will be approved phase by phase, progress report and relevant documents for the next phase must be submitted for review.*
10. *The committee reserves the right to site visit to follow up how the research project being conducted.*
11. *For external research proposal the dean or head of department oversees how the research being conducted.*

2. Ethic Committee of National Brain Center Hospital

KEMENTERIAN KESEHATAN REPUBLIK INDONESIA
DIREKTORAT JENDERAL PELAYANAN KESEHATAN
RUMAH SAKIT PUSAT OTAK NASIONAL Prof. Dr. dr. MAHAR MARDJONO JAKARTA
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RESEARCH ETHICS COMMITTEE
NATIONAL BRAIN CENTER HOSPITAL
PROF. Dr. dr. MAHAR MARDJONO JAKARTA

LETTER OF STATEMENT

No : LB.02.01/KEP/072/2021

After reviewing the research proposal and protocol below, the Research Ethics Committee of National National Brain Center Hospital Prof. Dr. dr. Mahar Mardjono Jakarta stated that the research entitled :

"Association between Sensory of Fingertip and Hand Function in Individuals with Stroke"

Principal Investigator : Orisa Elfath
Institution : Chulalongkorn University

The research implementation can be approved on the condition that :

1. Does not conflict with human values and research code of ethics
2. Report if there are any amendments to the research protocol
3. Report deviations/violations against research protocol
4. Periodically reporting on research developments and final reports
5. Report unwanted events/ adverse event/ serious adverse event

This agreement is valid fom the date of stipulation until the research implementation deadline as stated in the protocol with a maximum validity period of 1 (one) year.

Jakarta, 27 September 2021

Chair of the Research Ethics Committee

dr. Ita Muharram Sari, Sp.S

REFERENCES

VITA

NAME	Orisa Elfath
DATE OF BIRTH	22 November 1995
PLACE OF BIRTH	Magelang, Indonesia
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PUBLICATION	Proceeding (accepted) Journal (Submitted)