CHAPTER II
THEORETICAL REVIEW

A. Concept of Stroke Disease

1. Definition

Stroke is a neurological deficit condition that appears suddenly due to a vascular disturbance in the form of a reduced oxygen supply to the brain for more than 24 hours, resulting in brain tissue damage and impaired body function corresponding to the affected area.

2. Etiology

According to Sperber et al. (2024), there are four main causes of stroke, namely:

a. Ischemic Thrombosis, the formation of a blood clot in a brain vessel that blocks blood flow.

b. Cerebral embolism, a condition in which a blood clot or other particle moves and blocks a cerebral artery.

c. Ischemia, a reduction in blood flow to a brain area so that the tissue does not receive sufficient oxygen and nutrients.

d. Cerebral hemorrhage, namely the rupture of a cerebral blood vessel that causes bleeding into the surrounding tissue or space. This condition stops the blood supply to the brain and can lead to disruption of the entire body system.

3. Risk Factors

According to Nindrea & Hasanuddin (2023), the risk factors that play a role in the occurrence of stroke are very diverse, but in general can be grouped into two main categories, namely:

1) Non-modifiable risk factors

a. Age

As age increases, a person's risk of experiencing a stroke, particularly a recurrent event, increases significantly. This is caused by degenerative processes in the vascular system, such as hardening of the arteries, which increase susceptibility to stroke.

b. Gender

There are differences in stroke risk levels between men and women. This difference is thought to be influenced by hormonal factors, for example the protective role of estrogen in women against cardiovascular disease before menopause.

c. Family History (Genetics)

Genetic factors play an important role in increasing a person's susceptibility to stroke. Individuals who have family members with a history of stroke tend to have a hereditary predisposition, for example related to blood clotting disorders or vascular abnormalities.

d. Racial (Ethnic) Differences

Racial or ethnic variation is often associated with differences in stroke risk, which arise from a combination of biological, environmental, and lifestyle factors typical of a particular population group. For example, the prevalence of hypertension, which is a major risk factor, tends to be higher in certain ethnic groups.

2) Modifiable risk factors

a. Ischemic Heart Disease

Patients with a history of ischemic heart disease have more than twice the risk of experiencing a recurrent stroke. This condition is related to impaired coronary blood flow that can trigger the formation of thrombi that travel to the cerebral circulation.

b. Atrial Fibrillation

Arrhythmia in the form of atrial fibrillation increases the risk of recurrent stroke by almost twofold. The main mechanism is the formation of blood clots in the atrium that can travel to the cerebral circulation, thereby causing ischemic stroke.

c. Hypertension

High blood pressure is one of the strongest determinants. Uncontrolled increases in blood pressure can accelerate atherosclerosis, trigger plaque rupture, or cause rupture of cerebral blood vessels.

d. Obesity

Excess body weight contributes to metabolic dysfunction, insulin resistance, and an increased risk of atherosclerosis. A high body mass index at stroke onset is correlated with the need for more intensive rehabilitation.

e. Diabetes Mellitus

Chronic hyperglycemia worsens vascular damage and accelerates the atherosclerosis process. Several studies have shown diabetes to be a significant predictor of increased stroke risk.

4. Pathophysiology

Stroke is a neurological condition that arises suddenly due to disruption of blood flow to brain tissue. This circulation is primarily maintained by the internal carotid arteries and vertebral arteries, which supply oxygen and nutrients to brain cells. When blood flow is disrupted, whether due to blockage (ischemia) or rupture of blood vessels (hemorrhage), brain cells experience a lack of oxygen and glucose within minutes, triggering a cascade of cellular damage that can lead to neuronal cell death if not treated immediately.

5. Classification

Stroke is broadly divided into two types, namely hemorrhagic stroke (bleeding), marked by a large amount of bleeding within the closed cranial cavity, and ischemic stroke (blockage), marked by little to no bleeding.

1. Ischemic Stroke

Ischemic stroke occurs when blood flow to the brain is stopped so that the tissue lacks oxygen and nutrients. This type accounts for approximately 80-85% of cases and can be caused by cerebral thrombosis due to atherosclerosis, cerebral embolism from a clot originating elsewhere in the body, or systemic hypoperfusion that reduces overall blood flow to the brain.

2. Hemorrhagic Stroke

   Hemorrhagic stroke is caused by the rupture of a cerebral blood vessel, causing blood to damage the surrounding tissue. This condition has a higher mortality rate than ischemic stroke. Its main forms are intracerebral hemorrhage, which occurs within the brain tissue itself, and subarachnoid hemorrhage, which occurs in the space surrounding the brain.

6. Complications

   According to Kusuaningrum et al. (2024), stroke does not only cause acute neurological deficits, but also has the potential to cause various complications that can worsen the patient's prognosis. These complications can be grouped into several categories as follows:

   1) Neurological complications are often a direct manifestation of brain tissue damage.

      a. Cerebral edema occurs due to an inflammatory response and disruption of blood-brain barrier permeability. This condition increases intracranial pressure, decreases cerebral perfusion, and has the potential to cause herniation if not managed promptly.

      b. Post-stroke seizures are reported in 5-15% of cases, more often in hemorrhagic and cortical strokes. Seizures increase the brain's oxygen demand, thereby worsening ischemia. This requires careful monitoring and management.

      c. Patients with uncontrolled risk factors (hypertension, diabetes, dyslipidemia) are prone to recurrent stroke attacks. This underscores the importance of secondary therapy such as blood pressure control and lifestyle modification.

2) Musculoskeletal complications occur because post-stroke motor deficits have implications for biomechanical disturbances.
   a. Spasticity arises due to the loss of supraspinal inhibition of spinal interneurons. High muscle tone can impair mobility and cause contractures, thereby hindering rehabilitation.
   b. Post-stroke shoulder pain (hemiplegic shoulder pain) is associated with rotator cuff muscle weakness and shoulder subluxation.
   c. Osteoporosis and fractures are long-term complications of immobilization. Decreased physical activity reduces mechanical bone stimulation, thereby increasing the risk of fracture, especially in the affected extremities.
3) Systemic complications occur due to prolonged immobilization
   a. Impaired swallowing reflex (dysphagia) makes patients prone to aspirating food or fluids into the airway. Aspiration pneumonia is the leading cause of mortality in the acute phase.
   b. Urinary tract infections are often associated with the use of a urinary catheter. In addition to increasing morbidity, recurrent infections can worsen the patient's hemodynamic condition.
   c. Deep Vein Thrombosis (DVT) occurs due to venous stasis from immobilization, accompanied by hypercoagulability. Pulmonary embolism resulting from DVT can be fatal if not prevented through early mobilization.
4) Cognitive and Psychosocial Complications
   a. Cognitive impairment and vascular dementia, in which stroke can damage brain areas responsible for memory, attention, and executive function.

b. Post-stroke depression is influenced by both biological and psychosocial factors, which negatively affect the rehabilitation process.

c. Communication disorders (aphasia, dysarthria) cause obstacles to social interaction and the patient's quality of life.

5) Nutritional and Metabolic Complications

a. Malnutrition occurs due to difficulty swallowing and reduced food intake. Malnutrition slows tissue healing, decreases immunity, and increases the risk of infection.

b. Dehydration and electrolyte imbalance are often found, especially in patients with limited fluid intake or the use of diuretic therapy. This can worsen the prognosis because it is associated with an increased risk of thrombosis.

7. Supporting Examinations

According to Setiawan (2021), several examinations can be performed for stroke, as follows:

1) Computed Tomography Scanning (CT Scan), which specifically shows the location of edema, the position of a hematoma, and the presence and exact position of any infarcted or ischemic brain tissue.

2) Magnetic Resonance Imaging (MRI): determines the position and extent of cerebral hemorrhage. The examination results usually show the area experiencing lesions and infarction resulting from hemorrhage.

3) Electrocardiograph (ECG): shows a graph of heart rate to detect heart disease that may underlie the stroke as well as high blood pressure.

4) Electroencephalogram (EEG): identifies problems arising from and the impact of infarcted tissue, which reduces electrical impulses within brain tissue.

5) Angiogram: helps determine the specific cause of the stroke, such as arteriovenous bleeding or rupture, and to find the source of bleeding such as an aneurysm or vascular malformation.
6) Skull X-ray: shows changes in the pineal gland on the side opposite an expanding mass, calcification of the internal carotid artery in cerebral thrombosis, and partial calcification of the aneurysm wall in subarachnoid hemorrhage.

8. Management

a. Medical Management

Medical efforts for stroke patients usually include the administration of diuretics to reduce cerebral edema, which generally peaks three to five days after the cerebral infarction occurs. In addition, patients may also be given anticoagulants to prevent the occurrence or worsening of thrombosis or embolization originating from the cardiovascular system. Antiplatelet medication is also often prescribed, given the important role of platelets in the process of thrombus and embolus formation (Sperber et al., 2024).

b. Non-Pharmacological Management

In addition to medical therapy, stroke patients also require non-pharmacological interventions focused on the recovery of motor and sensory function as well as daily quality of life. This therapy can be carried out at healthcare facilities or at home with family assistance. Several widely used forms of non-pharmacological therapy include:

1) Bobath Therapy (Neurodevelopmental Treatment/NDT)

This method is carried out by guiding the patient to repeat certain movements gradually and repeatedly, so that abnormal movement patterns can be corrected into more normal patterns (Hayuningrum et al., 2023).

2) Range of Motion (ROM)

ROM exercises help patients train the movement of their extremities to maintain joint flexibility and prevent stiffness, so that the range of motion remains optimal (Mukhtar, 2024).

3) Dumbbell Exercise

A functional exercise using a small ball-shaped weight with a handle in the middle (dumbbell) as a load to increase strength, endurance, and body flexibility (Octavianus et al., 2024).

4) Hand Ball Grasping Exercise

A functional exercise that uses a grip ball to stimulate strength and coordination, as well as improve hand grip ability. This exercise is beneficial in the rehabilitation of patients with hand muscle weakness (Rahmawati et al., 2021).

5) Proprioceptive Neuromuscular Facilitation (PNF)

This exercise utilizes proprioceptor stimulation through specific movements in certain patterns to increase muscle strength, flexibility, and coordination. PNF is often used to improve body movement function after stroke and to increase neuromuscular control as well as muscle strength (Setyawan, 2022).

B. Concept of Body Extremities

1. Definition

The body extremities are parts of the body that protrude from the trunk and function as the body's main organs of movement. Anatomically, the body extremities consist of two major parts, namely the upper extremities and lower extremities, each of which has a different structure and function but is interconnected in carrying out human motor activities (Dewi et al., 2025). According to Astuti (2024), the extremities are the peripheral parts of the body composed of the musculoskeletal system, nervous system, and circulatory system, which work synergistically to produce movement and maintain posture. The structure of the extremities consists of bones that function as the supporting framework, muscles as the active movers, joints as connectors between bones, and nerves and blood vessels that regulate the supply of impulses and nutrients to these tissues (Habsari et al., 2024).

In nursing care, the body extremities are one of the important focuses in assessing a patient's functional status. The condition of the extremities can reflect a person's level of independence in performing Activities of Daily Living (ADL) such as walking, dressing, eating, and other productive activities. Disorders of the extremities, whether due to injury, aging, or disease, can cause a significant decline in functional ability and affect an individual's quality of life. Therefore, maintaining the strength, flexibility, and coordination of the extremities is an important part of maintaining overall physical health (Smeltzer & Bare, 2020).

In addition to functioning as organs of movement, the body's extremities also play a role in maintaining homeostasis and the body's adaptation to the environment. The extremity muscles, for example, contribute to energy metabolism and blood circulation through rhythmic contractions that help venous return to the heart (Setyawan, 2022). The bones of the extremities also function as storage sites for important minerals such as calcium and phosphorus, and play a role in hematopoiesis (blood cell formation), which occurs in the bone marrow (Astuti, 2024). This shows that the extremities have not only a mechanical function but also a vital physiological one for the continuation of life. Evolutionarily, the human extremities have undergone adaptations that enable humans to stand upright (bipedal posture) and perform complex activities using their hands (Muslimin, 2021). This adaptation makes human extremities more flexible and multifunctional compared to other living creatures, so that humans can perform activities that require high strength, precision, and coordination, such as working, exercising, and creating.

2. Types of Body Extremity Disorders

Body extremity disorders are one of the major complications frequently experienced by post-stroke patients and are the dominant cause of functional activity limitations. Stroke causes brain tissue damage due to disrupted blood supply, thereby affecting the central nervous system's ability to regulate motor function, sensory function, and movement coordination (Boentert, 2023).

1. Paralysis or Weakness of the Extremities

   Hemiparesis and hemiplegia are the most common complications after a stroke. This causes survivors to experience muscle stiffness, prolonged muscle weakness, and dependence in ADLs. In addition, there is difficulty walking, maintaining balance, speaking, chewing or swallowing, holding objects, coordinating movements, numbness, and weakness (Purba & Utama, 2019). Hemiplegia is a condition in which one side of the body is difficult to move, while hemiparesis is weakness on one side of the body without paralysis. Hemiplegia is defined as total paralysis of one side of the body due to damage to the brain area that controls voluntary movement, while hemiparesis is weakness of one side of the body without total paralysis, but still accompanied by decreased strength and movement coordination (Vanoglio et al., 2024).

2. Spasticity

   Spasticity is a muscle tone disorder characterized by increased resistance to passive movement that is velocity-dependent. This condition occurs due to the loss of supraspinal inhibitory control over spinal reflexes, causing the stretch reflex to become hyperactive. In the upper extremities, spasticity often affects the elbow, wrist, and finger flexor muscles, causing the upper extremity posture to tend toward flexion and stiffness. Spasticity not only limits joint range of motion but also disrupts normal movement patterns, causes pain, and increases the risk of contractures if not adequately treated. This condition is one of the main obstacles in the post-stroke upper extremity rehabilitation process (Kurniawan et al., 2025).

3. Movement Coordination Disorders

Movement coordination disorders in the upper extremities after stroke occur due to disrupted integration between the motor, sensory, and vestibular systems. Damage to the brain areas responsible for regulating the timing, accuracy, and smoothness of movement causes patients to experience difficulty coordinating complex movements. Clinical manifestations of this disorder include uncoordinated movements, intention tremor, and difficulty performing fine movements that require high precision. Coordination disorders significantly affect a patient's ability to perform daily activities such as writing, eating, and dressing (Purba & Utama, 2019).

4. Sensory and Proprioceptive Disorders

Sensory disorders are conditions characterized by decreased or lost ability to feel touch, pressure, temperature, pain, and joint position and movement (proprioception). This disorder occurs due to damage to sensory pathways or sensory cortical areas of the brain. In the upper extremities, sensory disorders cause a reduction in the sensory feedback needed to accurately control movement. As a result, patients experience difficulty gripping and manipulating objects, and have an increased risk of injury due to an inability to recognize dangerous stimuli (Purba & Utama, 2019).

5. Limited Joint Range of Motion

Limited joint range of motion in the upper extremities after stroke can be caused by prolonged immobilization, spasticity, pain, and changes in soft tissue structures such as muscles, tendons, and ligaments. This condition causes joint stiffness and decreased flexibility, thereby worsening upper extremity function limitations. Limited joint range of motion that is not treated properly can develop into permanent contractures and further hinder the recovery of motor function (Tongpangmeren et al., 2023).

C. Concept of Muscle Strength

1. Definition

   Muscle is a body part that acts as an active organ of movement that enables movement to occur. The muscle's ability to contract and relax is due to muscle strength. Muscle strength is the ability of a muscle or group of muscles to produce tension or force against resistance in a single maximal effort. A muscle with good strength is one that is able to contract and relax optimally. With strong and healthy muscle condition, the body can maintain balance and carry out daily activities (Mukhtar, 2024; Dewi et al., 2025).

2. Factors Influencing Stroke-Induced Muscle Weakness

   Stroke causes muscle weakness through damage to brain tissue that disrupts the motor pathways and neural control of muscle contraction, so that motor impulses from the cortex to the muscles cannot be optimally transmitted. As a result of this disruption, there is decreased muscle activation, changes in tone, and reduced voluntary movement control, which leads to post-stroke muscle weakness. According to Qi et al. (2024), several factors that influence stroke-induced muscle weakness are as follows:

   a. Damage to the Motor Cortex

      Stroke can damage the motor cortex area responsible for controlling body movement. This part is located in the frontal lobe of the brain, and if it is disrupted due to stroke, the brain's ability to send commands to the extremity muscles will be impaired. This condition can cause weakness or even paralysis of the limbs such as the hands and feet.

   b. Disruption of the Corticospinal Pathway

      The corticospinal pathway is the main nerve pathway that connects the brain to the body's muscles to convey motor commands. A stroke affecting this pathway, whether in the brain or spinal cord, can result in weakness or paralysis on the side of the body opposite the location of the damage. For example, if a stroke occurs in the left hemisphere of the brain, hemiparesis usually appears on the right side of the body.

c. Disruption of Brain-Body Neural Connections

In addition to the motor cortex, stroke can also affect other brain structures such as the basal ganglia or cerebellum, which function to regulate coordination and control of movement. Damage to these areas results in impaired balance, coordination, and muscle control. As a result, muscle weakness in the extremities becomes increasingly apparent and affects the patient's functional ability.

3. Factors Influencing Muscle Strength

According to Dewi et al. (2025), several factors that influence an individual's muscle strength are as follows:

a. Intermuscular Coordination

This factor relates to the interaction between groups of muscles in an activity that involves many muscles at once. If coordination between muscles works well, the force produced will be more optimal. Conversely, poor coordination can cause muscle work to be less than maximal.

b. Intramuscular Coordination

Muscle strength is also influenced by the nerve activity that controls muscle fibers in a movement. The more muscle fibers activated during exercise, the greater the strength produced. Maximal results can be achieved through exercise with a progressively appropriate load.

c. Muscle Response to Nerve Stimulation

Muscle contraction can occur when an electrical impulse in the form of an action potential is transmitted along a motor nerve until it reaches the nerve ending connected to the muscle. This mechanism determines the muscle's ability to respond to stimuli and produce contraction.

d. Joint Angle

Muscle strength is also influenced by the joint angle position during movement. Maximum conditions usually occur when the joint is in a straight or near-straight position. Research shows that a joint angle of around 90-100 degrees produces greater muscle strength because contraction occurs more efficiently at that position.

e. Age

As age increases, muscle strength tends to decrease due to the process of sarcopenia, namely the reduction in muscle mass and quality. Elderly individuals generally have lower muscle strength than younger individuals due to muscle fiber degeneration and decreased neuromuscular function. Several studies mention that one cause of muscle weakness is the leakage of calcium from proteins within muscle cells, which disrupts optimal muscle contraction.

f. Muscle Fiber Type

Differences in muscle fiber type also affect strength. Type I fibers (slow twitch) have high resistance to fatigue, so they play a greater role in long-duration endurance activities. Conversely, type II fibers (fast twitch) fatigue more quickly and are relatively weaker, although they can produce strength in a short amount of time.

g. Level of Daily Activity

Regular physical activity can maintain and even increase muscle strength. A person who is active in daily movement generally has stronger muscles than those who are less active. This is because muscles that are used consistently will adapt and maintain their function.

h. Electrolytes

Electrolytes play an important role in maintaining basic cell function, especially in conducting electrical impulses in nerves and muscles. Substances such as sodium, potassium, calcium, magnesium, chloride, phosphate, and bicarbonate are needed to produce action potentials and support muscle contraction. Electrolyte imbalances can directly impact muscle weakness and dysfunction.

i. Frequency of Stroke Attacks

Recurrent strokes can worsen a patient's condition. Each time an attack occurs, the risk of brain damage increases, thereby worsening motor ability. As a result, muscle function continues to decline, increasing disability and the risk of death.

4. Functional Characteristics of Muscle

According to Dewi et al. (2025), there are several functional characteristics of muscle, namely:

a. Contractility

The ability of a muscle to contract or shorten, thereby enabling movement to occur. This contraction process is influenced by the interaction of the proteins actin and myosin within the muscle fiber.

b. Extensibility

Muscle has the property of being able to lengthen or stretch without being damaged. When a muscle is in a relaxed state, it is able to return to its normal length after previously contracting.

c. Elasticity

After a muscle has been stretched or contracted, it has the ability to return to its original shape. This elastic property allows the muscle to spring back to its initial condition.

d. Tone

Even when not fully contracting, a muscle still maintains a baseline level of contraction called tone. The function of tone is to maintain body posture and provide stability to the joints.

e. Excitability (Reactivity)

Muscle is able to respond to stimuli from the nervous system by contracting. This ability is important for maintaining movement coordination and providing a rapid reaction to various stimuli.

f. Coordination

In producing movement, a muscle works together with other muscles and body systems synergistically. For example, when lifting a load, several muscle groups contribute simultaneously so that the movement runs effectively.

g. Adaptability

Muscle can adapt to various types of activity and training. For example, strength training can increase muscle mass, while aerobic exercise increases endurance.

h. Fatigue

After performing strenuous activity, a muscle can experience a decreased ability to contract. This condition is usually caused by the accumulation of metabolic products, such as lactic acid, within the muscle fiber.

5. Stages of Muscle Mechanism

The muscle mechanism is a complex process involving interaction between the nervous system and muscle fibers to produce contraction. According to Icih Tresnaasih (2020), the stages of the muscle mechanism are as follows:

1) The first stage begins when a nerve impulse reaches the neuromuscular junction and triggers the release of acetylcholine. This neurotransmitter then causes depolarization of the muscle cell membrane, which subsequently causes the release of calcium ions (Ca^{2+}) from the sarcoplasmic reticulum.

2) The second stage is marked by an increase in calcium ion concentration within the muscle cell. These ions bind to the protein

troponin, triggering a conformational change in troponin and shifting the position of tropomyosin. This change exposes the active site on the actin filament so that it can interact with the myosin filament.

3) Next, in the third stage, ATP molecules are broken down to produce the energy needed by the myosin head. This energy allows myosin to pull actin toward the center of the sarcomere, resulting in muscle shortening. This process occurs simultaneously in many myofibrils within the muscle cell, so that muscle contraction occurs as a whole.
4) In the fourth stage, the myosin head releases actin when a new ATP molecule binds again. This binding breaks the actomyosin bridge and allows the contraction cycle to repeat. After the ATP is broken down, the myosin head is ready to interact with actin again, so that contraction can continue to occur as long as energy and calcium ions are available.
5) The final stage is muscle relaxation. The contraction process can only continue as long as sufficient ATP and calcium ions are available. When the nerve impulse stops, calcium ions are pumped back into the sarcoplasmic reticulum, so that the calcium concentration in the cytoplasm decreases. This causes tropomyosin to once again cover the active site of actin, the actin-myosin interaction stops, and the muscle returns to a relaxed state.
6) Measurement of Muscle Strength

   Manual Muscle Testing (MMT) is one of the most commonly used forms of muscle strength examination because its procedure, interpretation of results, validity, and reliability have been well established (Habsari et al., 2024). Manual muscle testing has been used for more than a century. MMT involves the use of observation, palpation, and the application of pressure by the examiner to determine muscle strength action. In the absence of movement, palpation and observation are used to see whether the associated muscle is active. When movement is present, observation is used to estimate the range of the completed test action.

According to Trisnowiyoto as cited in (Setyawan, 2022), there are several procedures that affect MMT results, namely:

1) Position

The therapist or nurse should be able to position the patient so that MMT can be performed. The patient's position is highly dependent on the muscle being examined. The relevant part of the patient's body should be loose or free to move.

2) Range of Joint Motion

Some muscles that must be examined do not always need to have full ROM. Also, in certain conditions, such as when a patient has a contracture so that the ROM becomes limited, the MMT interpretation of "full ROM" refers to however much ROM the patient currently has.

3) Palpation

Palpation is needed to ensure the correct muscle is being examined, so that the MMT performed remains valid; it also prevents substitution by other muscles that are not being examined.

a) Resistance is applied perpendicular to the segment being examined. Resistance can be applied either from the beginning to the end of the movement, or alternatively, only at the end of the movement.
b) Stabilization is performed to prevent muscle substitution
c) Muscle substitution occurs when a coordinated movement is caused by the relevant muscle being weak; substitution can be anticipated through proper positioning, accurate muscle palpation, and appropriate stabilization.
d) Patient motivation, in which the desire to move can affect the MMT score result

e) Pain felt by the patient can affect the patient's motivation, which in turn will also affect the MMT results.

Table 2.1 Manual Muscle Testing (MMT) Assessment of the Upper Extremity1

Grade	Score	Description
Normal	5	The muscle is able to move independently through the full ROM against gravity and maximal resistance.
Good	4	The muscle is able to move independently through the full ROM against gravity and moderate resistance.
Fair	3	The muscle is able to move independently through the full ROM against gravity with minimal resistance
Poor	2	Able to perform movement but not yet against gravity.
Trace	1	There is a muscle contraction or tone, but no movement at all.
Zero	0	No muscle tone at all

Source: (Hermawan and Wihardja, 2020)

D. Concept of Proprioceptive Neuromuscular Facilitation (PNF) Therapy

1. Definition

Proprioceptive Neuromuscular Facilitation (PNF) is an exercise therapy method that focuses on neuromuscular facilitation to improve body movement function. The PNF technique works by utilizing proprioceptive impulses to facilitate movement. The basic principle of this method is to provide specific stimulation to reactivate latent mechanisms and the body's reserve potential, so as to produce normal and coordinated functional movement. Basically, PNF provides stimulation to proprioceptors to increase neuromuscular activity so that the resulting response becomes easier to achieve. The neuromuscular system then prepares this movement as a response to the demands of the activity. Neuromuscular facilitation is the process of providing stimulation to proprioceptors to support the neuromuscular mechanism, so that the movement response can occur more easily and efficiently (Simbolon, Susilo & Wahyudi, 2022). The intervention dose is set at once a day, three times a week, for a period of three months (Leksonowati et al., 2022).

2. Benefits

Muscle weakness in stroke patients is a consequence of disrupted blood flow to the brain, which causes damage to nerve tissue, particularly in the motor cortex and corticospinal pathway responsible for controlling voluntary movement. This damage disrupts the transmission of nerve impulses from the central nervous system to the muscles, thereby reducing the muscle's ability to contract optimally and causing a decrease in strength, coordination, and control of extremity movement. In the post-stroke phase, muscle weakness often persists due to an incomplete nerve recovery process, accompanied by decreased use of the affected extremity, changes in muscle tone such as spasticity, and limited sensorimotor stimulation needed to support neural reorganization. If not treated appropriately, this condition can worsen motor dysfunction and hinder the recovery of upper extremity function.

Proprioceptive Neuromuscular Facilitation (PNF) therapy is an effective rehabilitation approach for addressing post-stroke muscle weakness through the provision of targeted, intensive, and repeated sensorimotor stimulation. The main benefit of PNF therapy is that it helps increase range of motion, improve muscle strength, increase flexibility, and restore motor function disrupted by injury or a neurological condition such as stroke (Nugraha et al., 2020). In stroke patients, PNF is effective in stimulating weak muscles, reducing spasticity, and improving functional movement patterns. This therapy is not only intended to increase strength, but also aims to improve coordination, flexibility, and movement control through a combination of muscle contraction and relaxation techniques (Muslimin, 2021).

Research by Ni et al. (2024) shows that structured PNF exercise is able to significantly increase upper extremity muscle strength, coordination, and motor control compared to conventional exercise, indicating the success of PNF in supporting the neuroplasticity process. Similar results were reported by Syokumawena et al. (2024), who found a statistically significant increase in upper extremity muscle strength (p-value = 0.001) in 34 non-hemorrhagic post-stroke patients after undergoing PNF exercise for three months. In addition, Nugraha et al. (2020) and Muslimin (2021) concluded that PNF is effective in increasing range of motion and flexibility, reducing spasticity, and improving functional movement patterns through a combination of muscle contraction and relaxation techniques. Based on these findings, recent studies recommend the development of PNF interventions carried out intensively and continuously, combined with other functional exercises focused on daily activities, in order to increase the effectiveness of rehabilitation and clinical relevance in post-stroke patients.

3. Types of Therapy Techniques

According to Setyawan (2020), to perform PNF exercise there are several basic exercise principles that need to be applied, namely:

1) Patterns to Facilitate Response: The PNF technique uses a pattern for each movement. The movement patterns performed are spiral and diagonal movements that are closely related to continuous movement that functions normally.
2) Optimal Resistance is a substantial resistance adjusted to the patient's condition and applied to the contracting muscle. At this stage, resistance is given using hand strength and held for a moment during the movement. This movement aims to increase muscle strength.
3) Manual Contact: This technique provides facilitation for the activity's needs through hand contact that provides stimulation to exteroceptors.

4) Traction and Approximation (pulling and compression): Pulling and compression are very effective for stimulating proprioceptors originating from joint structures.
5) Verbal Stimulation (commands): The verbal command given is an instruction, which can stimulate the patient's effort to form a movement.

According to Alfen (2024), there are several techniques in PNF exercise that can be used according to the patient's needs, including:

1) Rhythmic Initiation

   This technique begins with passive movement by the therapist, followed by active movement by the patient, then resistance is added to the movement. This pattern can be applied to both agonist and antagonist muscles. It is generally used in patients with rigidity, severe spasm, ataxia, slow movement, or limited mobility.

2) Repeated Contraction

   This is an isotonic technique for the agonist muscle. After part of the movement is performed, a restretch is given so that the contraction becomes stronger. At each phase when strength decreases, the therapist provides a repeated pull so that the contraction increases. Restretch can be performed up to four times within one diagonal pattern.

3) Stretch Reflex

   This technique utilizes muscle stretching to facilitate contraction. The muscle is positioned in a lengthened state, then given a slow pull followed by a quick pull in three directions. After the stretch reflex appears, optimal resistance is given to strengthen the movement response.

4) Combination of Isotonics

   This technique combines concentric and eccentric contractions of the agonist muscle without a pause or stop, performed at a slow tempo so that the movement remains controlled.

5) Timing for Emphasis

This movement emphasizes extra stimulation on the weak part of the muscle. The strong part of the muscle is held, while the weak part is allowed to move, so that the weakness can be more effectively facilitated.

6) Hold Relax

This technique uses isometric contraction of the shortened antagonist muscle to reduce tension. The patient holds the contraction according to the therapist's command, then relaxation is performed so that the agonist muscle can be moved further. This technique is useful for increasing joint range of motion.

7) Contract Relax

In this technique, the patient performs a maximal isotonic contraction of the shortened antagonist muscle. After reaching the limit of movement, the patient is instructed to "pull" or "push," followed by relaxation so that the joint range of motion can be gradually increased.

8) Slow Reversal

This technique is performed with alternating isotonic contractions between the agonist and antagonist muscles without a relaxation pause. The movement starts with the stronger pattern, then switches to the weaker pattern with added resistance or an increased joint range of motion.

4. PNF Movement Patterns for the Upper Extremity

Movements in PNF are not performed in a straight line, but rather follow diagonal and spiral patterns that are considered more natural and resemble body movement during daily activities. The basic movement pattern involves three main components, namely flexion-extension, abduction-adduction, and internal or external rotation. These three components are combined into a diagonal pattern that involves more than one joint and muscle group simultaneously, producing a more complex yet functional movement. In the upper extremity, there are two main patterns that are often used, namely D1 and D2, each having a combination of flexion and extension movements.

a. D1 Flexion Pattern

Involves the shoulder in a position of flexion, adduction, and external rotation, combined with forearm supination and flexion of the wrist and fingers. This movement resembles the activity of bringing the hand to the mouth, for example while eating.

b. D1 Extension Pattern

Conversely, D1 extension involves the shoulder in a position of extension, abduction, and internal rotation, with forearm pronation and extension of the wrist and fingers, resembling the movement of moving the hand downward and outward after eating.

Figure 2.1 D1 Flexion-Extension Pattern1
Source: (Sethi & Yashendra, 2024)

c. D2 Flexion Pattern

Involves the shoulder in a position of flexion, abduction, and external rotation, with forearm supination and extension of the wrist and fingers. This movement resembles the activity of taking an object from a top shelf.

d. D2 Extension Pattern

Involves the shoulder in a position of extension, adduction, and internal rotation, with forearm pronation and flexion of the wrist and fingers, resembling the activity of directing the hand toward a trouser pocket.

Figure 2.2 D2 Flexion-Extension Pattern2
Source: (Sethi & Yashendra, 2024)

E. Concept of Hand Ball Grasping Therapy

1. Definition

Hand Ball Grasping is a form of rehabilitation exercise therapy that focuses on improving hand grip function using a ball-shaped or cylindrical object as a medium. The main principle of this therapy is to train the contraction and relaxation of the hand muscles through the repeated movement of gripping and releasing a ball. This exercise can be performed using a therapy ball with a certain size and elasticity suited to the patient's ability (Wulaningsih et al., 2025). In post-stroke patients, this therapy is beneficial for stimulating neuromuscular activity, strengthening the hand muscles, and improving fine motor control, which is often impaired. The intervention dose is set at twice a day, for two weeks (Rahmawati et al., 2021).

2. Benefits

Hand Ball Grasping therapy provides various benefits, particularly in the rehabilitation of post-stroke patients experiencing upper extremity muscle weakness. This exercise can increase hand grip strength through activation of the flexor and extensor muscles, thereby supporting functional abilities such as holding, writing, or using everyday tools. In addition, this therapy also helps improve fine motor coordination because it involves repeated movements that stimulate the connection between the central nervous system and peripheral muscles (Wulaningsih et al., 2025).

3. Hand Ball Grasping Therapy Movements

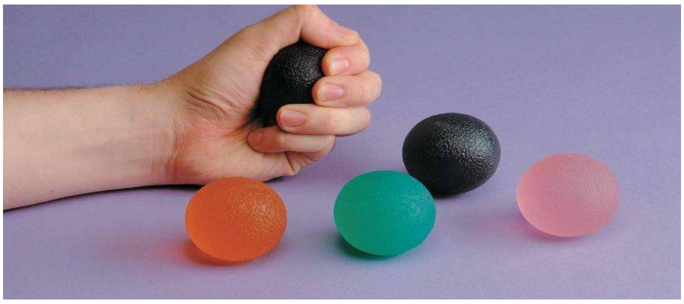

Figure 2.3 Rubber Ball3
Source: (Heryanti and Puspita, 2022)

1) Before performing the therapy, patients are advised to warm up by moving the elbow toward the upper arm (flexion) and straightening the upper arm back out (extension).
2) Ball grip (wrist up): Hold the ball in the palm of the hand. Open the hand so it faces upward. Grip the ball firmly in the palm, hold, and relax. Repeat.
3) Ball grip (wrist down): Hold the ball in the palm of the hand. Turn the hand so it faces downward. Squeeze the ball in the palm. Hold and relax. Repeat.
4) Pinch: Place the ball between the thumb and index finger. Squeeze together. Hold and relax
5) Thumb extend: Place the ball between the bent thumb and two fingers of the same hand. Roll the ball, extend, and straighten the thumb.

6) Opposition: Place the ball in the palm of the hand. Maintain contact between the thumb and fingers during the exercise. Bring the thumb and fingers together. Hold and relax the hand.
7) Extend out: Place the ball on a table. Place the fingertips on top of the ball. Roll the ball outward on the table.
8) Side-Squeeze: Place the ball between any two fingers. Bring the two fingers together. Hold and relax.
9) Finger bend: Place the ball in the palm of the hand with the fingers pressed into the ball. Push the fingers into the ball as you bend the fingers. Hold, then relax.

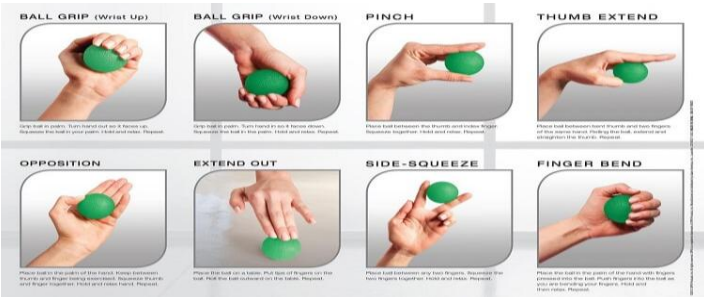

Figure 2.4 Hand Ball Grasping Exercise Movement4
Source: (Heryanti and Puspita, 2022)

F. Concept of Dumbbell Exercise

1. Definition

Dumbbell Exercise is a form of fitness exercise that uses a tool called a dumbbell, a small weight with a handle in the middle, used to train muscle strength and endurance. This exercise functions to increase skeletal muscle mass and improve overall physical function of the body (Artasonia et al., 2024). In addition, Dumbbell Exercise falls into the category of progressive resistance exercise, in which the load is increased gradually to stimulate muscle contraction, particularly the arm muscles, thereby helping the process of muscle recovery and strength improvement (Oktavianus et al., 2024)

2. Benefits

Dumbbell Exercise provides a variety of benefits to the body, particularly in increasing muscle strength and mass. In addition, this exercise also plays a role in shaping the biceps muscles, relieving muscle tension, and improving posture and bone structure. Other benefits include increased self-confidence, prevention of osteoporosis, increased joint flexibility and range of motion, and helping with fat burning and body metabolism (Oktavianus et al., 2024). In its application, weight training is generally performed using approximately 50% of the maximum load an individual is able to lift (Patandianan et al., 2019). One variation of exercise medium that can be used is a light weighted ball weighing approximately 56-59 grams (Artasonia et al., 2024).

3. Dumbbell Exercise Equipment

Resistive exercise using dumbbells is one of the methods used in the rehabilitation of post-stroke patients experiencing upper extremity muscle weakness. The size and weight of the dumbbells used vary, generally ranging from 0.5 kg, 1 kg, to 2 kg, and the selection must be adjusted to the level of muscle weakness, recovery phase, and the patient's motor control ability. Loads of 1-2 kg are generally used in post-stroke patients whose muscle strength has already improved or who are in an advanced rehabilitation phase, because such loads require better neuromuscular control and higher muscle tolerance. However, the use of heavier loads in the early phase, or in patients with moderate to severe weakness, risks increasing muscle fatigue, triggering improper movement compensation, and worsening spasticity.

Conversely, several studies recommend the use of light loads (≤0.5 kg) as a safe and effective initial option for post-stroke patients. Ada et al. (2006) reported that strength training with light to moderate loads did not increase spasticity and instead provided a meaningful increase in muscle strength when performed in a controlled manner. Research by Lee et al. (2019) showed that upper extremity exercise using a 0.5 kg load in post-stroke patients was able to increase muscle strength and movement control without causing side effects such as pain or increased muscle tone. In addition, Bohannon (2015) emphasized that lighter loads are more suitable for neurological populations because they allow patients to maintain movement quality and perform sufficient repetitions, which is important for supporting the neuroplasticity process.

In this study, a dumbbell weighing 0.5 kg was used. The selection of this load was based on considerations of safety, patient tolerance, and effectiveness of muscle stimulation. This load is considered sufficient to provide initial resistance capable of stimulating voluntary muscle contraction without causing excessive fatigue or risk of injury. In addition, the use of a 0.5 kg dumbbell allows post-stroke patients with upper extremity muscle weakness to exercise consistently, maintain correct movement patterns, and increase participation in the rehabilitation program.

Figure 2.5 Dumbbell Equipment5

Source: (Hidayat and Munandar, 2022a)

4. Dumbbell Exercise Movements

Dumbbell Exercise movements are performed using a dumbbell, a small weight with a handle in the middle that functions to train muscle strength through various movements such as biceps curls, triceps extensions, and shoulder presses. This exercise aims to increase strength, coordination, and flexibility (Hidayat & Munandar, 2022). In post-stroke patients, movements are performed gradually with light loads to be safe and to help restore muscle function. Regular exercise can improve movement control and overall functional ability of the body.

a. The patient sits in a relaxed position; ask the client to perform the Dumbbell Exercise.
b. Movement by lifting the dumbbell above the head, then lowering it, repeated 3 times.
c. Hold the dumbbell in the hand. Keep the arm straight, raise the arm to the side to shoulder height, then lower it, repeated 3 times.
d. Lean the body slightly forward, hold the elbow behind, straighten the elbow while lifting the weight behind, then bend the elbow. Make sure the elbow remains behind, only moving the arm from the elbow down, repeated 3 times.
e. Hold the weight in the hand, bend the elbow then straighten the elbow, repeated 3 times, or can be performed with both elbows simultaneously.
f. Push the arm upward and back down, both hands holding the dumbbell.

G. Effect of Proprioceptive Neuromuscular Facilitation (PNF) and Hand Ball Grasping Therapy

Post-stroke patients generally experience various neurological deficits that affect muscle strength, movement coordination, and the ability to perform daily activities. Medical management is indeed a major part of preventing worsening of the condition and complications, but recovery of function is not sufficient with pharmacological therapy alone. A non-pharmacological approach that focuses on physical, cognitive, and psychosocial rehabilitation is also needed so that patients can become independent again. Non-pharmacological therapy is very important, especially for treating muscle weakness, because structured physical exercise can help reactivate weak muscles, improve coordination, and increase motor strength. Therefore, the provision of non-pharmacological therapy to post-stroke patients is an important part of a comprehensive management plan to support optimal recovery.

One non-pharmacological approach widely used in stroke rehabilitation is exercise therapy based on Proprioceptive Neuromuscular Facilitation (PNF). This therapy works by facilitating neuromuscular activity through diagonal and spiral movement patterns given resistance, so that it can reactivate weak muscles and increase motor strength (Nugraha et al., 2020). Hand Ball Grasping therapy is also a simple yet effective intervention option, because it focuses on improving hand grip ability through the repeated movement of gripping and releasing a ball. This exercise not only strengthens the intrinsic and extrinsic muscles of the hand, but also improves fine motor coordination, which is often impaired in post-stroke patients.

Based on the results of a study conducted by Nauko et al. (2024), carried out over 1.5 months on 15 stroke patients experiencing muscle weakness at the Tani dan Nelayan General Hospital, Boalemo Regency, combining strengthening exercise and PNF, it was shown that there was a significant effect of the Proprioceptive Neuromuscular Facilitation (PNF) intervention on the increase in hand muscle strength value, with a difference in hand muscle strength value between the PNF intervention and strengthening exercise (p-value 0.039), where PNF was better at increasing hand muscle strength than Strengthening Exercise.

The results of a study by Syokumawena et al. (2024) on 34 post-stroke patients at Puskesmas Merdeka Palembang, South Sumatra, found that the PNF intervention carried out for three months with a therapy dose of once a day, three times a week, significantly increased muscle strength (p-value 0.001) in post-stroke patients, particularly in the upper limbs, using a Hand Dynamometer (CAMRY) as the measuring instrument. PNF exercise was performed with an initial warm-up for 10-15 minutes, followed by PNF exercise consisting of three movements. Each movement lasted 30 seconds with a 10-second relaxation period between movements.

H. Theoretical Framework

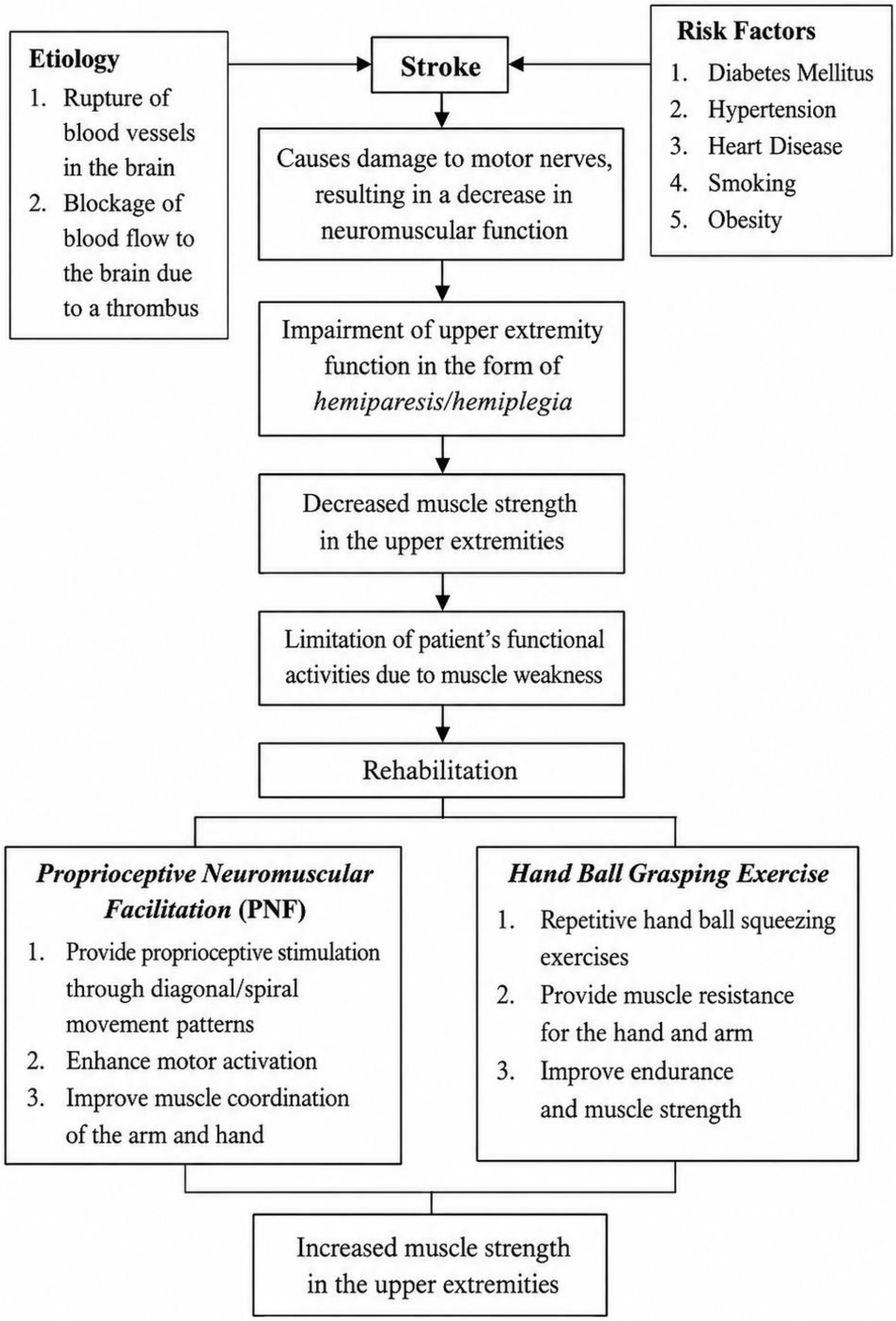

Chart 2.1 Research Theoretical Framework1
Source: (Abdu et al., 2022), (Nauko et al., 2024), (Yani & Anggraini, 2025)