A Review of the Evolution and Advancements of Neurological Physical Therapy

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Abstract – Over the years, the discipline of neurological physical therapy has undergone modifications, with a shift in focus from muscular weakness to non-muscular issues. Neurofacilitation and Proprioceptive Neuromuscular Facilitation (PNF) are methods designed to improve both the flexibility and muscular power of people. The rehabilitation environment and the duration of physical activity are also crucial. The advancement of robot-assisted therapy and the implementation of suitable training methodologies have the potential to enhance the functionality of individuals with neurological impairments. This research examines the advancement of neurological physical therapy and the advancements achieved in treatment techniques aimed at enhancing functional mobility. This article explores the influence of early research in neurophysiology and experimental models on therapeutic approaches, highlighting the need of incorporating advancements in neurology into clinical practice. The research emphasizes the importance of motor learning, muscle biology, biomechanics, and exercise science in optimizing motor performance and facilitating functional motor recovery.

Keywords – Neurorehabilitation, Neurological Physical Therapy, Neurorehabilitation Therapy, Proprioceptive Neuromuscular Facilitation.

I. INTRODUCTION

Neurorehabilitation operates on the premise that motor recovery after injury is influenced by motor learning. Nevertheless, there is little knowledge about the impact of brain damage on the process of learning, the interaction between learning processes and natural biological healing, and the most effective ways to integrate principles of learning into rehabilitation training programs. In this context, we differentiate between two categories of motor learning: adaptation and skill acquisition. We will explore their connection to neurorehabilitation. Functional recovery may be achieved by resolving impairments, which involves regaining the movement patterns that were present before the injury. It can also be achieved by compensation, which involves using other motions or body parts to achieve the same objective. Both of these types of recovery can be improved through training procedures.

The current focus in neurorehabilitation therapy is to quickly achieve independence in everyday tasks by using compensatory measures, rather than aiming to reduce disability. Animal studies demonstrate that after localized ischemia injury, there exists a short period of heightened plasticity, lasting roughly 3-4 weeks. During this time, when combined with training procedures, significant improvements in motor function may be achieved. Similarly, the vast majority of improvement in humans recovering from impairment happens within the initial 3 months following a stroke. This implies that focusing on addressing impairment during this specific time period using rigorous motor learning protocols could result in functional gains that are of similar magnitude to those observed in animal models.

Rehabilitation therapies should be administered with a high level of intensity, including the dosage, frequency, and length of training, and incorporating demanding practice. These specific aspects of practice are believed to be essential in activating adaptive processes in the brain, which provide significant restructuring and enable stroke patients to effectively use their most damaged limb in everyday situations even after treatment concludes. Nevertheless, the precise quantity of repetitions required for effective motor learning in individuals after a stroke remains uncertain. Research conducted on animal stroke models has shown that a significant number of repeats of motor activities are required to produce enduring brain modifications [1], persons with a neurological injury need a larger number of movement repetitions to produce gains in motor outcomes compared to healthy persons, particularly those with more serious brain abnormalities.

For instance, Meyer et al. [2] discovered that healthy individuals needed approximately 20 repetitions of a movement to enhance their performance (both speed and accuracy) in a reaching task. On the other hand, stroke patients required more than double that number to achieve a similar outcome (up to 55 repetitions for those with significant upper limb weakness). The issue of determining the appropriate dosage in rehabilitation therapies remains unresolved, primarily because there is no agreement on the definitions of training intensity. The concept of intensity, as established in [3], only considers the duration of treatment sessions without considering the potential variation in the number of movement repetitions done within the given therapy hour. Presently, the redefinition of training intensity involves calculating the ratio of repetitions to the duration of treatment in minutes. Animal studies indicate that the quantity of repetitions may have a greater impact on motor recovery than the overall duration of treatment. Hence, the intensity of treatment is established based on the frequency of repetitions within a certain time period, the duration of each training session, the overall number of sessions, and the scheduling of sessions per day or week.

This research investigates the progress made in neurological physical therapy and the breakthroughs obtained in treatment strategies that seek to improve functional mobility. This article examines the impact of first studies in neurophysiology and experimental paradigms on therapeutic methods, emphasizing the need of integrating breakthroughs in neurology into clinical application. The remaining portion of the article has been structured in the following manner: The second section describes the evolution of neurological physical therapy. This section starts by describing the origins of neuro-facilitation approaches, developments in the 1980s, and approaches of hybridization. The third section discusses the advancements in rehabilitation techniques for motor impairments, such as re-evaluation of functional effects of impairments, optimization of motor performance, motor learning, and rehabilitation environment. The fourth section discusses the delivery process of physical therapy, identifying the intensity of skill practice and exercise. The fifth, and final section presents the summary of the research.

II. THE EVOLUTION OF NEUROLOGICAL PHYSICAL THERAPY

Gaining insight into the historical progression of physical therapy practice allows us to contemplate the evolution and clinical practice advancements. It also instills a sense of reassurance that clinical practice should be responsive and adaptable to emerging scientific information. The neurological physical therapy history serves as a prime example of the process of transformation. In the early 20th cent, practitioners used muscle re-education and corrective exercise techniques. The latter included training specifically targeting particular muscles, taking into account the functions of synergistic muscles. Clinicians in their practice used information that primarily emphasized structural anatomy and workout concepts as comprehended during that period. A significant portion of the persons undergoing physical therapy suffered from muscular weakness and paralysis caused by poliomyelitis. The focus of attention shifted as the incidence of poliomyelitis decreased over time due to the introduction of new preventative treatments. Additionally, during the second world war, the arrival of a large number of young adults with severe brain damage played a significant role in driving the advancement of novel therapies.

Origins of the neurofacilitation approaches

During the 1950s, there was a significant change in the field of neurological physical therapy as new treatments, such as neurofacilitation or neurophysiological, were created. The attention shifted from the muscular components to the non-muscular components. The methods focused largely on the neurological system, using stimulation of the neural system to enable movement. The task of Butler et al. [4] in Neurodevelopmental Therapy (NDT) or Bobath Therapy and the techniques of movement facilitation by Hindle et al. [5], known as Proprioceptive Neuromuscular Facilitation (PNF), were significant influences.

PNF is a stretching method used to enhance muscle suppleness and has been shown to have a beneficial impact on both passive and active range of movements. Current research has mostly focused on evaluating the effectiveness of the intervention on certain outcome measures, including muscular strength, passive range of motion (PROM), peak torque, and active range of motion (AROM). This study is crucial for justifying its use in therapeutic and athletic environments to facilitate injury rehabilitation via the acquisition of AROM and PROM, as well as enhancing performance. Therapists in clinical settings currently use PNF techniques to rehabilitate patients who have had soft tissue injury or undergone invasive procedures, aiming to restore their functional range of motion (ROM) and enhance their strength.

Presently, scientific research has shown that proprioceptive neuromuscular facilitation (PNF) approaches have been shown to enhance range of motion (ROM) according to studies conducted by Faridah et al. [6]. The literature often presents two strategies, namely the contract-relax-antagonist-contract method (CRAC) and the contract-relax method (CR), as the most frequently seen in the field of proprioceptive neuromuscular facilitation (PNF). The CR approach included elongating and maintaining the target muscle (TM) in a certain posture, while the participant exerted maximal isometric contraction on the TM for a predetermined duration.

Subsequently, there was a brief TM relaxation period, often with a passive stretch. The CRAC technique replicated the same mechanism of the method of CR, but extended it beyond its original scope. Instead of simply extending the TM without any active effort, the participant intentionally tightened the muscle of antagonist to the TM for an additional specified duration. PNF has been shown to enhance muscle performance when included into training routines. Performing PNF before exercise may actually reduce performance of muscles. Nevertheless, studies have shown that performing PNF either after exercise or independently can enhance muscular performance. To sustain these enhancements, both in terms of range of motion (ROM) and muscular performance, it is essential to engage in a minimum of two sets of proprioceptive neuromuscular facilitation (PNF) exercises every week.

These therapeutic techniques are often known as eponymous since they were stated after their originators. The originators' diverse and even contradictory views were influenced by their understanding of early neurophysiological works. They used experimental paradigms, such as stimulus-response processes, often using animal models. Therapeutic techniques that aim to enhance mobility by stimulating sensory receptors in muscles, joints, and the skin. Their approach was founded on the concept of the rejuvenating impact of promoting developing movement patterns, with a focus on maintaining proper posture and facilitating natural movement patterns. Krause, Szecsi, and Straube [7] believed that before facilitating more normal movement, it was necessary to normalize muscle tone by using ways to reduce spasticity, which refers to aberrant postural tone. Their perspective was that engaging in physically demanding activities would heighten spasticity and, as a result, should be abstained from. Curiously, these techniques disregarded advancements in neurology, particularly those concerning the context-dependent characteristics of shifting.

Developments in the 1980s

The treatment techniques mentioned above, especially those developed by Heim [8], were prevalent throughout the latter half of the 20th century and continue to be extensively used. Nevertheless, within this period, there emerged recent advancements as physiotherapists and other individuals with scientific literature access endeavored to disseminate new scientific discoveries into clinical application. These advancements capitalized on experimental research that specifically examined the process by which people gain expertise in motor learning or movement, muscle biology and psychology, and its adaptability. These advancements mostly demonstrated the growing availability for physiotherapists to participate in postgraduate programs, allowing them to enhance their research abilities and engage in in-depth study of specialized scientific areas. Unsurprisingly, they saw the practical consequences in a medical context.

The initial efforts to develop therapeutic techniques for enhancing functional movement were primarily based on inductive reasoning, which involved seeking theoretical explanations for observed phenomena. This approach may have been influenced by the limited availability of a comprehensive scientific understanding of human movement, which could have facilitated more deductive derivation of clinical implications. In recent decades, advancements in technology and evolving understanding of the functioning of the human nervous system have led to a significant increase in research related to movement. This research, particularly in the sectors of neuroscience and biomechanics, has clear implications for clinical practice.

The experimental methods have transitioned from a reductionist approach, which primarily studied stretch reflex operations in animal frameworks, to a comprehensive investigation of movement control operations in humans. This inquiry encompasses both performance and physiological aspects. Advancements in electromyography (EMG) and motion analysis technology have facilitated the examination of many motions, like standing up, walking, and reaching to collect an item. These studies provide detailed information about the movement patterns and forces involved in each activity, including the particular changes made to maintain posture. Emerging brain imaging techniques allow for the investigation of structural changes taking place inside the brain and the potential influences of experiences, namely the impact of use patterns and learning.

The surge in therapeutically significant study discoveries concerning movement has facilitated the advancement of neurological rehabilitation via a more deductive approach. Theoretical scientific principles were used to draw clinical implications, and novel clinical methodologies were devised and evaluated. For instance, a reasonable biomechanical model has been developed for the sit-to-stand action, which serves as the foundation for standardized rules on how to train this movement. This paradigm has furthermore offered techniques for quantifying performance, and a heightened emphasis on clinical research is allowing us to evaluate the effectiveness of therapies.

Hybridization

Nevertheless, the transition process may prove challenging for both educators and professionals, leading to a tendency to blend contemporary approaches with traditional ones that are still being used. This may happen even in the absence of any substantiation for the efficacy of the previous approaches. Throughout the history of scientific pursuit, there have consistently been endeavors (often failed) to combine novel approaches with traditional ones at periods of significant transformation. The process of combining different elements or components is referred to as hybridization. The shift towards hybridization may be persuasive, and the argument for reconciling conflicting paradigms may seem appealing on the surface. Hybridization may appeal to a physiotherapist who is hesitant to abandon traditional therapy procedures and transition to new ones. Nevertheless, opposing paradigms exhibit philosophical and conceptual disparities, stemming from variations in knowledge such as the organization of the system or the kind of deficits after a lesion.

III. ADVANCEMENTS IN REHABILITATION TECHNIQUES FOR MOTOR IMPAIRMENTS

Re-evaluating the Functional Effects of Impairments

The importance of practicing in order to progress by adapting to new information is effectively shown by analyzing recent research that is altering our perspective on limitations resulting from damage to the system of upper motor neuron. A reassessment of the proportional impacts of muscular weakening and modifiable modifications in muscles, like heightened spasticity and rigidity, is prompting substantial changes in therapeutic practice. The belief that spasticity is the primary cause of dysfunction movement has resulted in the creation of techniques that aim to reduce or suppress spasticity in order to promote more typical movement patterns. This perspective has had significant influence in recent decades. Historically, physical therapy has not placed much emphasis on addressing muscle weakness, since it was believed that spasticity was the major factor contributing to weakness and handicap. In line with this perspective, therapists have refrained from engaging in exercises that demanded exertion (such as strength training) due to the belief that this exertion would exacerbate spasticity.

The current research supports the idea that paralysis, weakness (lack or decreased muscle strength), and dexterity loss (impaired motor control) are the main impairments that hinder functional conduction after upper motor neuron lesions. These findings are crucial for designing appropriate interventions. Our growing knowledge indicates that soft tissue adaptations resulting from muscular weakness and inactivity after an injury might have a detrimental effect on the ability to restore function. Adaptations of soft tissue encompass heightened stiffness of muscle, which is a mechanical reaction to strain on a non-contracting muscle, as well as the functional and restructuring reorganization of both connective and muscle tissue. Weakness of muscle stems from two main causes: firstly, from the lesion itself, which leads to a decline in descending inputs that converge on the population of final motor neuron, resulting in a decrease in the number of motor units available for recruitment.

Furthermore, the brain injury might lead to a reduced rate of firing in motor units and disturbed synchronization of motor units. These variables result in the disruption of voluntary motor output at the segmental level and may be the underlying cause of the motor control difficulties seen in patients, even when they are capable of producing some force of muscle. Impaired motor performance may be more strongly influenced by the loss of power generation (force multiplied by velocity) rather than a reduction in force production. The capacity to produce substantial muscular forces is of little practical advantage if the motion is executed at a sluggish pace that hinders effectiveness. Beyaert, Vasa, and Frykberg [9] have shown a reduced power output after a stroke, and a clinical observation of this is the sluggishness of movement often seen in individuals post-stroke. Skeletal muscles undergo adaptations in response to the degree of exertion placed upon them24. Consequently, secondary weaknesses emerge due to reduced muscular activity and immobility. There is growing data that demonstrates a correlation between muscular strength and function.

The importance of spasticity, which is characterized by increased reflex activity in response to stretching at different speeds, in relation to the recovery of motor function is yet uncertain. There is insufficient evidence to suggest that reflex hyperactivity plays a substantial role in movement impairment after a stroke. According to some studies, stretch reflex hyperactivity may occur sometime after the injury, indicating that it can be a reaction to non-functional, constricted inflexible muscles that has adapted over time. Spasticity is often used in clinical practice to describe an increased resistance to passive movement, however it is important to note that mechanical and functional alterations in the muscle are likely to play a significant role. Commonly used clinical assessments, such as the Ashworth Scale, lack the ability to differentiate between the respective effects of heightened muscular rigidity and reflexive hyperactivity.

Optimizing Motor Performance

Our collaborative research has evolved over time, focusing on human movement and incorporating new scientific developments and evidence from clinical studies on intervention effects. The primary study topics that guide our work are exercise science, motor control mechanisms, motor learning (skill acquisition), biomechanics, and muscle biology,. An important aspect to note is that there is a heavy emphasis on incorporating ideas and data from disciplines outside of physical therapy. This highlights the fact that physical therapy is a clinical science that is implemented in practice.

Our research in recent decades has concentrated on the patient's role as a learner and the importance of training or task-oriented exercise, together with fitness training and strength, to enhance the patient's ability to acquire skills of motor and maximize performance of functional motor. Several studies [10, 11, 12] examining this theoretical framework have seen beneficial outcomes in persons with brain damage. Evidence of enhanced functional performance indicates that learning has occurred. Moreover, a sufficiently rigorous training regimen may enhance muscular endurance and elicit a cardiovascular training response. The results indicate that when strength is specifically focused on, there is an observed improvement in resistance of strength and, in some instances, enhanced functional performance. However, the degree of muscular weakness may determine whether or not strength training leads to enhanced functionality. Curiously, strength training does not lead to heightened resistance to hypertonus (passive movement) or excessive reflex activity (spasticity).

In order to enhance performance in a certain activity, it is crucial that the exercise be tailored to that task and its context. This is because motor control and muscular strength are dependent on the precise action being done and its surrounding circumstances. Proficient execution requires not only the production of enough muscular strength, but also the precise modulation, maintenance, and synchronization of force from several muscles to govern bodily movement throughout the whole activity. Specifically, the production of muscular strength must be rapid enough to satisfy the requirements of the work.

The available research indicates that physical therapy treatment should prioritize the promotion of limb use. Training entails altering the work and ecosystem to enable active engagement of the weakened limbs. The use of a treadmill (TT) for walking training shows promise as a strategy for retraining gait and improving cardiovascular fitness, endurance, and speed,. The load for system of musculoskeletal may be altered by adjusting BWS (body weight support), which can either raise or reduce it. Additionally, the walking pace can be regulated. TT enhances the repetitive walking pattern and may cause a transition towards equal timing and longer duration of the affected limb's stance phase. Transcranial magnetic stimulation (TT), whether with or without brainwave synchronization (BWS) assistance [13], is a method used to enhance the intensity and quantity of practice. Dependent walkers may only have the option of using TT with BWS to practice walking during the first stage of recovery.

An analysis of many research on treadmill training after stroke, both with and without body weight support (BWS), revealed a tendency towards improved gait speed when BWS was used in conjunction with aggressive speed targeting. This approach was shown to be more successful compared to other therapies. Additionally, some studies demonstrated considerable improvements in endurance. Research indicates that incorporating TT into a task-oriented training program is more effective than NDT for improving walking ability after an acute stroke, and more effective than sham therapy for individuals with chronic stroke. Upon further examination of the material, it becomes apparent that the crucial element in this research is the inclusion of diverse and rigorous practice of tasks related to movement. Additionally, there is data indicating the transfer of skills from treadmill training (TT) to walking on regular terrain. Furthermore, the training for walking on the ground involves navigating obstacles and adapting to various situations, while also requiring diverse levels of cognitive effort.

Hirsch et al. [14] coined the term “learned non-use” after conducting a series of monkey research. They suggested that this phenomenon would explain why some persons struggle to use their damaged upper limb, even when there is enough muscular activation. Constraint-induced movement therapy (CIMT) [15] is a treatment method that entails restricting the mobility of the non-affected limb for a prolonged time while engaging in demanding task-focused exercise of the affected limb. A recent systematic review discovered increasing evidence that favors the usage of Constraint-Induced Movement Therapy (CIMT) over other treatments or no therapy at all. Additional evidence is derived from findings indicating a correlation between enhanced motor performance, heightened limb use, and brain reorganization. It is crucial to consider the impact of certain therapies on the functional abilities of the limb in everyday activities, such as the Actual Amount of Use Test or Motor Activity Log.

There is a growing fascination with the potential of neuromuscular electrical stimulation (ES) to decrease the occurrence of secondary flexible alterations in muscles, to activate extremely or denervated weak muscles, and to prevent the stretching of the glenohumeral joint capsule and rotator cuff muscles. Electrical stimulation facilitates recurrent muscular activity in persons with limited voluntary movement during the early stage of their condition. The field of rehabilitation in ES has a rich and diverse historical background. The results of two extensive evaluations indicate that the usage of ES may decrease subluxation of shoulder, particularly in the immediate period, and maybe alleviate shoulder discomfort. Integrating sensory information from an electromyography (EMG) alert with electrical stimulation (ES) in persons who can partly engage weakened muscles but cannot produce enough muscular contraction for practical reasons might potentially assist in task-oriented exercise. Both assessments indicate the importance for more investigation.

Neural reorganization and functional recovery

Understanding the processes that facilitate motor recovery after damage to the sensorimotor cortex is now starting to become apparent. research conducted on animals have shown that the adult cerebral cortex has the ability to undergo extensive functional reconfiguration. Similarly, research using neuroimaging and other non-invasive mapping techniques on people have also provided strong evidence supporting this claim [16, 17]. These investigations have shown that undamaged cortical tissue proximal to the injury and more distant cortical regions may exhibit plasticity in both functional topography and architecture. Active use, learning, and experience of the damaged limbs have a crucial role in modulating the adaptive reconfiguration that happens following cortical injury, which is essential for recovery. Based on current research, it is probable that in order to achieve optimal brain remodeling and functional recovery, it is necessary to prioritize difficult, engaging, and meaningful task training to facilitate learning (e.g., as shown in [18, 19, 20]). Furthermore, study results demonstrate substantial improvements and increased adaptability of the structure when therapy is initiated at an early stage, indicating that postponing the start of rehabilitation may diminish the treatment effectiveness.

Motor learning

As physiotherapists, we are recognizing increasingly that patients are actively involved in their training rather than just receiving treatment passively. The notion that motor learning research may offer a substantial amount of scientific knowledge to direct clinical practice has been accessible to the profession for some decades.

Skilled performance refers to the efficient and consistent execution of an activity to achieve a certain objective with little effort. Motor learning is not immediately observable. It refers to a series of intricate internal processes that may be deduced from a continuous enhancement in the execution of a task, specifically, a stable alteration in motor behavior due to repeated practice of that task. In order to assess the improvement in performance, the therapist evaluates the performance of individual at the beginning of the training, at different intervals allover the rehabilitation process, and regularly after the person has been discharged to see whether the performance improvements have been sustained.

Scientists have been studying the process of skill acquisition for many decades. Initially, they focused on healthy adults who were training to develop a particular talent. More recently, Motahar and Wiese [21] have also started investigating individuals with motor disabilities. Renshaw et al. [22] outline the process of learning as first grasping the concept of the movement, followed by acquiring the skill to modify the pattern of movement to meet ecosystem requirements. During the early phases, individuals acquire the ability to focus on the essential aspects of the task and actively participate in the process of practicing. Viewing the patient as a learner entails creating surroundings and delivery techniques that promote the acquisition of skills.

During the process of training, the therapist may redirect the attention of patients from focusing on internal bodily sensations (such as the movement of their upper body or feet) to an exterior focus that is directly linked to the desired outcome (such as avoiding obstacles on the floor). As muscular strength, motor control, and ability improve, the learner's center of attention might change. During walking, the focus of attention might change from the feet to the surroundings. Similarly, the primary concern during the sit-to-stand movement can vary from the initial positioning of the feet and the acceleration of the upper body's forward rotation, to the task of maintaining stability while standing up and holding a glass of water. Recent studies involving healthy individuals have shown the significant impact on performance and skill improvement when learners shift their attention towards the outcome of the action (external focus) rather than the movement itself (internal focus).

Expert performance, as described by Ericsson and Charness [23], is defined by the capacity to execute intricate motions, while being adaptable enough to adjust actions according to changing environmental requirements, all while minimizing the amount of effort used. This principle is equally applicable to routine activities like walking and getting up from a chair, as well as to leisure, athletic, or occupational activities. Expertise is limited to a certain job. While level walking and stair walking may exhibit comparable biomechanical properties, they impose distinct demands on the person. The person acquires the ability to modify and adjust the fundamental movement pattern in accordance with various circumstances. When crossing the street at pedestrian lights, it may be necessary to walk faster, whereas navigating steps or barriers in the home necessitates different adjustments to one's walking gait.

To enhance a certain activity, one must engage in deliberate practice of that action. This entails repeatedly practicing in order to become proficient and efficient in reaching a given objective. For some people, enhancing the pace of action and optimizing power production may be significant objectives for performance improvement. Nevertheless, individuals with muscular weakness and impaired motor coordination below a certain threshold may be unable to engage in such training. To enhance strength and control, it may be essential to engage in exercises that target muscle force production. Additionally, practicing the desired motion under altered circumstances, such as rising from a raised seat that demands less muscular effort, might be beneficial. Multiple iterations of an activity are necessary to enhance physical power and enable the patient to cultivate an ideal technique for executing the task. The repetitious aspect of both strength training and skill training, which are crucial requirements in motor recovery, has been overlooked by physical therapy.

During the process of training functional activities, the therapist collaborates with the client to establish objectives, which are determined by an assessment of the person's skills. In the role of a "coach", the therapist can utilize their understanding of important biomechanical features to explain how a movement is structured. They can demonstrate the movement, give verbal feedback and instructions, guide the individual's visual focus, or draw attention to relevant cues in the surroundings, such as barrier`s height. Nevertheless, it is important for the patient to acquire the skill of coordinating their movements in accordance with the surrounding environment in order to accomplish these objectives. This may be achieved by consistent physical and mental training.

To ensure functional relevance, the environment should be arranged in a manner that includes items of varying sizes, weights, and graspability. This will enable the training of diverse activities. Goals are tangible rather than conceptual: "Extend your hand and grasp the glass from the table" instead of "Lift your arm". "Retrieve the glass from the floor by extending your arm laterally" instead of "Transfer your body's center of gravity to the left side". Holder, Krishnamurthi, and Theadom [24] have effectively shown the contrasting results that occur when persons who have had a stroke engage in goal-oriented activities that are directly connected to tangible items, as opposed to engaging in activities with more conceptual objectives. Thorne et al. [25] investigated a task where participants used one hand to collect coins from a table and transfer them to the other hand. Both able-bodied individuals and stroke patients participated in the study, sometimes using money and at other times imitating the action without currency. Both cohorts exhibited enhanced motor performance, characterized by increased speed, smoother trajectories, and improved accuracy, when executing the scooping task compared to imitating the activity.

Rehabilitation environment

If the restructuring of the brain and the recovery of its functions after brain injuries rely on the activity and usage, then the rehabilitation ecosystem is likely to have a significant impact on the results of patients. The rehabilitation environment comprises the physical or constructed surroundings, the approaches used for delivering rehabilitation (including intervention kind, intensity, and dose), and the staff members (their expertise, proficiency, attitudes, and teaching capabilities).

Animal trials provide evidence indicating that the characteristics of the ecosystem, including its physical system, as well as the chances it provides for physical contact and social contact, may impact the result after a lesion. Regarding animal study, the key factors that seem to significantly boost behavior include engagement with things that facilitate physical action, and a heightened state of arousal.

Observational studies conducted in rehabilitation facilities (for instance, in [26]) offer valuable insights into the daily activities of patients, indicating that the environment may not adequately support mental and physical engagement or social connection. Additionally, it may not effectively serve as a conducive learning ecosystem. Additional research indicates that a significant proportion of the patient's time is devoted to inactive activities rather than engaging in physical exercise. Hence, the matter of the duration and arrangement of time dedicated to physical activity, such as motor task practice, is of utmost importance in the field of rehabilitation.

IV. DELIVERY OF PHYSICAL THERAPY

The use of rigorous task-oriented training has necessitated modifications in the practice of physical therapy, including both the techniques employed and the manner in which it is administered. Physiotherapists are investigating various methods of arranging delivery to facilitate the patient's active engagement in learning. They are investigating the impact of a collaborative patient-therapist interaction, the influence of little group dynamics during training of circuit, and the outcomes of collaborative meetings among patients.

Coote and Stokes [27] have developed technologies, such as robot-mediated therapy (RMT), to help people spend more time practicing and improve their skills. Rehabilitation robots were first developed in the late 1980s. The following decade was a period of groundbreaking innovation [28]. Following the year 2000, the first instances of commercially accessible robots emerged. These devices may aid in the practice of upper or lower limb motions and the relearning of motor skills, as well as in the development of proprioception, cognitive processes, and attention. Patients have access to equipment that allows them to simulate the same actions as with the robots, but this equipment does not provide mechanical support. Therefore, patients must depend only on their own physical power. The focus is on frequent repetition, direct engagement, and personalized treatment. The objective is to achieve a greater degree of efficiency within a reduced timeframe. The underlying principle behind using robots in rehabilitation is not to replace the therapist, but rather to expand the range of available therapy alternatives.

The primary objectives of treatment with rehabilitation robots are to enhance upper limb functionality and facilitate gait re-education. Rehabilitation robots are typically used in the aftermath of central nervous system impairment, particularly in the case of stroke. Several clinical studies and meta-analyses have been carried out on these robots. In relation to the effectiveness of electromechanical arm training, Morgan et al. [29] conducted a comprehensive analysis of 45 randomized controlled studies including 1619 individuals. It was discovered that this kind of treatment enhances arm function and muscular strength, as well as the performance of everyday tasks. However, the procedures used in the investigations varied significantly, and a total of 24 distinct devices were utilized.

Robot-assisted treadmill training is a commonly used technique for retraining walking patterns. In their Cochrane review, Mehrholz et al. [30] examined 36 studies including 1472 people. They discovered that post-stroke patients who had this kind of training, in addition to standard physiotherapy, had a higher likelihood of achieving independent walking compared to those who just got traditional treatment.

The emphasis has been placed on motions of the upper extremities that are demanding, stimulating, and repetitive. A substantial increase in upper limb function improvement has been seen when comparing it to Bobath/NDT treatment of equivalent duration and intensity [31]. Furthermore, a single case study shown that the recovery rate was higher when therapy was administered with RMT compared to treatment or no treatment with sling suspension. The extent to which RMT may be used to different situations and its impact on the process of acquiring motor skills have not been evaluated yet.

Intensity of skill practice and exercise

Until recently, the level of cardiovascular stress and the intensity of task-oriented training caused by physical exercise have been overlooked in treatment for brain lesions. Endurance exercise, such as strength training after a stroke, has historically been overlooked because to the prevailing beliefs around spasticity. Patients must not only engage in practice to restore proficiency in doing tasks, but they must also prioritize the restoration of enough strength, endurance, and fitness necessary to execute these acts. There is enough evidence to support the fact that patients with stroke have reduced physical endurance upon being released from rehabilitation. Deconditioning may manifest during the first six weeks after a stroke. A research was conducted by Langhammer and Lindmark [32] to assess the exercise ability of patients at the first stage after a stroke. The patients underwent incremental maximum effort tests on a semi-recumbent cycle ergometer. Deconditioning may occur due to the lack of variation in traditional rehabilitation programs. This highlights the need of addressing the intensity of training early on after a brain injury to minimize the negative consequences of deconditioning.

In a recent study, Billinger et al. [33] examined the aerobic aspect of occupational therapy and physical therapy for stroke patients. They monitored the patients' heart rate using monitors for heart rate and tracked their therapeutic actions every two weeks for a total of 14 weeks. The primary discovery indicated that the treatment sessions consisted of low-intensity exercise and activity, which failed to generate sufficient metabolic stress to trigger a training response. Despite the expectation of increasing exercise intensities as functional status improves, there was no statistically significant rise in HRmean and

HRpeak. The negative impact of having limited exercise capacity and muscular endurance on one's ability to move effectively and resist fatigue might be worsened by the increased metabolic requirements of modifiable movements. Patients with stroke who are dismissed from rehabilitation and demonstrate advancements in their walking pattern may not necessarily be able to walk normally. They often struggle to maintain their most logical walking velocity comfortably, which suggests that the energy required for walking is high and their withstanding is poor. This further affects their ability to perform daily activities effectively.

The assessment of walking speed over a distance of 10 meters, which is often used as a clinical measure of gait, can provide an exaggerated estimation of locomotor ability after a stroke. Healthy individuals are capable of walking at a pace that exceeds their comfort level for a minimum duration of six minutes. Subjects who have had a stroke may struggle to sustain their preferred pace for the whole of the given time period. This would hinder their ability to become proficient in walking within the community, perhaps resulting in a progressive disability. These findings underscore the importance of engaging in endurance training and assessing endurance with a test like the 6-minute walk. Suitable training methods like graded treadmill walking, bicycle training, and strengthening and mixed aerobic activities have shown to enhance aerobic capacity in individuals with chronic stroke. As anticipated, the benefits are particular to the kind of exercise. The application of this concept to daily life is also evident in the observed improvements in overall health and well-being. Anand et al. [34] evaluated the overall physical activity level of their participants using the Human Activity Profile, a questionnaire consisting of 94 actions that are ranked based on their metabolic counterparts. The results showed the involved participants displayed increased ability to perform home tasks and displayed an increased leisure engagement level following the fulfilment of training sessions.

V. CONCLUSIONS

Over time, the field of neurological physical therapy has changed, with early practitioners primarily concentrating on muscle re-education techniques and therapeutic exercise. After then, attention turned to preventative strategies and the rehabilitation of World War II brain injury. Proprioceptive Neuromuscular Facilitation (PNF) and Bobath Therapy are two examples of neurophysiological therapies that were established in the 1950s. Even now, these techniques are still used in therapeutic and athletic settings. Research in the fields of neuroscience and biomechanics has significantly increased as a result of technological improvements and our growing knowledge of the human nervous system. The field of neurological rehabilitation has benefited from the introduction of scientific ideas and the creation of creative treatment plans thanks to this study. Research has shown that engaging in specific activity-focused exercise and training, together with strength and fitness training, may improve motor abilities and overall functional performance.

Optimizing performance requires tailoring workouts to objectives and circumstances. Furthermore, studies have looked at electrical stimulation and constraint-induced movement therapy as potential therapeutic modalities. Regaining motor function after sensorimotor cortex loss requires both neurological remodeling and functional rehabilitation. The process involves actively engaging, acquiring, and using the injured limbs, all of which support adaptive reorganization. Research on motor learning has shown that to improve skills, deliberate practice and an external focus are necessary. In addition to teaching and assessing, therapists play the role of coaches for their patients. However, patients also need to learn how to synchronize their motions with their surroundings. Patients' results may be impacted by the physical environment and rehabilitation facility.

Although there are now robot-assisted therapies available to help with motor skill training and progress, patients still need their own physical strength to get individualized care. Following damage to the central nervous system, rehabilitation robots have shown potential in improving upper limb functioning and retraining gait patterns. Exercise-induced cardiovascular strain and training intensity must be considered while treating brain lesions. Low-intensity exercise may not provide enough metabolic stress to cause a training reaction. Furthermore, those who have had a stroke could find it difficult to comfortably walk at their preferred pace. It has been shown that using the right training techniques, such as bicycle training and a combination of aerobic and strength-building exercises, may improve aerobic capacity and improve the overall health and well-being of those who are suffering from chronic stroke.

The field of neurological physical therapy has advanced via the incorporation of technology advancements and rigorous scientific research. Studies have shown that participating in targeted exercise programs, using personalized training methods, and prioritizing external variables may enhance motor skills and functional performance. Rehabilitation robots and appropriate training strategies may aid in the recovery process after central nervous system damage. Considering the amount of training intensity and cardiovascular stress, together with the influence of the rehabilitation setting, is crucial for assessing patient outcomes.

Data Availability

No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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Competing Interests
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