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Review Article

A Review on the Process of Neuromotor Rehabilitation of Patients with Brain and Spine Lesions and Developing Skills in Healthy People by Plasticity Analysis: A Systematic, Review

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Abstract

Introduction: Withing a short period of time up to six months after brain damage, the brain can be reconstructed and plasticity can be accelerated. Therefore, there is a possibility of recovering a collection of motions by rehabilitation within this time period. The present article investigated the process of neuromotor rehabilitation in patients with brain lesions, plus developed a skill in healthy people by analyzing the neuroplasticity and studied the changes of muscle synergy.

Method: The present Systematic, review researched the combination of terms such as rehabilitation(Mesh), neurorehabilitation(Mesh), brain stroke(Mesh), brain lesion(Mesh), skill (Mesh)with no time limit on scientific databases including Science Direct, Springer, Google Scholar, Pubmed, Scopus, SID, IranDoc, and Web of Science and the purpose of the research was specified on the basis of the articles found.

Results: Among the researched articles, 32 related articles were reviewed, the most important of which were investigated and analyzed included rehabilitation in stroke, rehabilitation, and spasticity, rehabilitation recovery mechanisms in spasticity after a stroke, comparison between the effects of rehabilitation after a stroke and healthy people, required after stroke training for patients, the effectiveness of repetition in the rehabilitation exercises after stroke.

Conclusion: The process of neuromotor rehabilitation of patients with brain lesions and the development of skills in them compared to healthy individuals by analyzing the degree of plasticity is an effective way to strengthen muscles and can be effective; However further investigation is needed.

Keywords: Stroke, Plasticity, Rehabilitation, Training.

Introduction

In recent years, due to the development of basic and clinical studies, the science of rehabilitation underwent basic changes and it considerably increased our understanding of motor learning, neuroplasticity (Figure 1), and rehabilitation [1].

According to the studies, the mechanism of change of the brain structure caused by neuroplasticity is executed through the recovery process and rehabilitation as motor learning. Concerning the recent advances, the vital role of neuroplasticity in the process of motor skill learning has been proven [2].

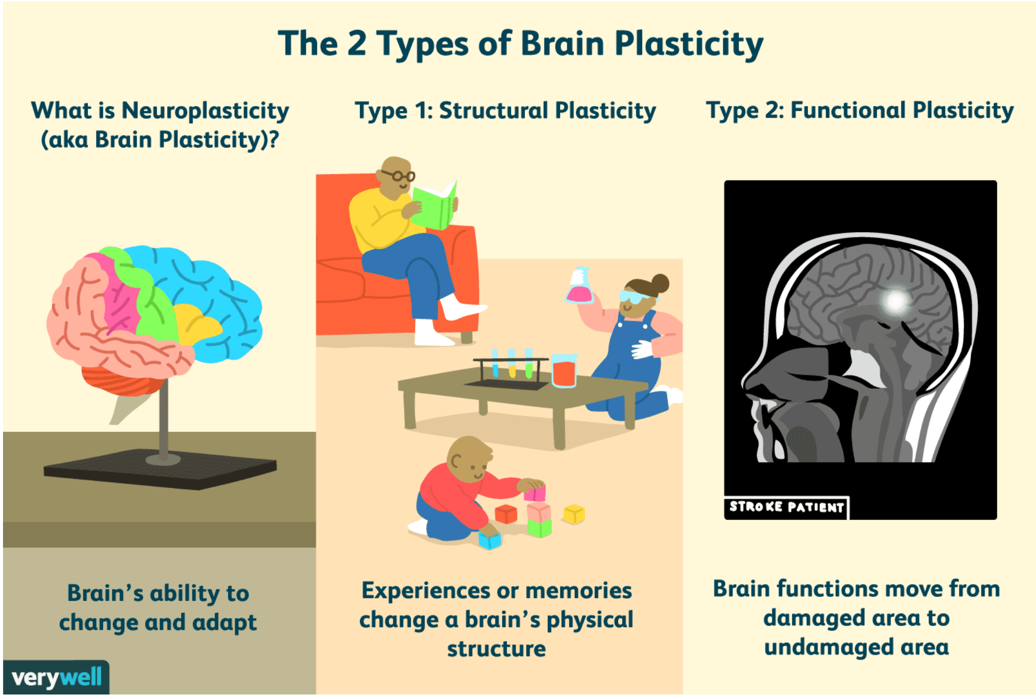

Figure1 Neuroplasticity

After a brain stroke (Figure 2), considerable changes occur in the synaptic system and neuroplasticity. The increase of cerebral cortex excitability, plus the changes in the synaptic plasticity such as long-term potentiation (LTP) of the calcium channels, and activation of neurotrophic factors in the damaged hemisphere are in fact the pertinent mechanism in improving brain stroke.

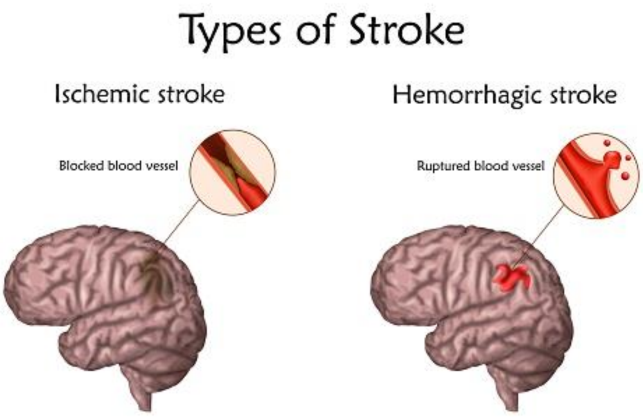

Figure 2 Type of brain stroke

Oxygen restriction that occurs at the time of brain stroke immediately reduces the natural performance of neurons and prevents maintaining the ionic gradient of two sides of natural cortex. This reduction in activating the neurons occurs on account of the loss of integrity of the input circuits from the adjacent tissues affected by infarct, edema, and reduction of the metabolic activities influence the recovery process. Motor recovery after brain stroke depends on the integrity of motor circuits and the interaction between the inflicted and healthy hemisphere.

Patients suffering from brain stroke undergo clear changes in the motor excitability of cerebral cortex. The recent studies suggested that brain modulation can enhance the positive effects of motor training in the rehabilitation process. The functional imaging techniques provide the possibility of investigating the neural correlation during the recovery process. Within a short period up to six months after brain damage, the brain can be reconstructed and plasticity can be accelerated.

Therefore, there is a possibility of recovering a collection of motions by rehabilitation within this period. The present article investigated the process of neuromotor rehabilitation in patients with brain lesions, further developed a skill in healthy people by analyzing the neuroplasticity, and studied the changes of muscle synergy.

Methodology

Initially, the research was conducted in the data center of the scientific databases such as Science Direct, Springer, Google Scholar, Pubmed, Scopus, SID, IranDoc, and Web of Science. The research was carried out by a combination of terms including rehabilitation, neurorehabilitation, brain stroke, brain lesion, and skill with no time limit.

According to the research type, the inclusion criteria of the research constituted intervention studies, review and experimental studies, type of participants (healthy people and brain stroke patients), and type of outcome (any outcome pertaining to the motor-physical recovery).

Taking into account the purpose of the present research, the data pertinent to the role of neuroplasticity in learning and motor rehabilitation were included in the study. First, 75 articles pertaining to the subject of the study were selected, and then among them and on the basis of a targeted selection method, articles with content pertinent to motion control, neuroplasticity, and brain stroke were selected (32 articles). It should be noted that the found articles were published in Persian and English.

Results

Thompson conducted a review on plasticity and its affecting factors, and also investigated the impact of plasticity in the recovery process of brain stroke patients [3].

Thompson first summarized the plasticity mechanism in four methods, and then studied the process of motor learning and rehabilitation after a brain stroke. Finally, they argued that using plasticity to change the structure of inflicted section in the process of rehabilitation after a brain stroke is a priority in comparison to the healthy section. Peng demonstrated that the mechanism of change of the brain structure resulted from motor learning is carried out during the process of recovering and rehabilitation, while it might take several years to develop special skills in healthy people [4].

Page *et al.* stated that in case patients with brain stroke carry out mental and psychological training besides physiotherapy sessions, it can lead to considerable progress in the rehabilitation process [5].

Quattromani *et al.* investigated the synaptic up to functional plasticity in the process of recovery after a brain stroke.

The data from animal models indicated that neuroplasticity in a limited time window after a brain stroke can be quite crucial in the recovery process of the patients. In this case, the plasticity mechanism including reestablishing the connections and strengthening synapse depends on the activity. The main challenge in improving the recovery process after a brain stroke is to understand the manner of utilization and optimal modification of neural networks to acquire new strategies to compensate for losing the damaged tissues. Thus, plasticity in patients with brain stroke has a parallel relationship with the plasticity mechanism in adults during the growth and adjustment of the neural system [6].

Maier *et al.* proposed a review to investigate the various rehabilitation strategies after a brain stroke by examining and emphasizing neuroplasticity. They argued that executing a rehabilitation plan should include meaningful and frequent teaching with diverse intensity and for a specific work in a variety of motions in an enriched environment to influence the neuroplasticity and result in recovering the motor function in patients [7].

Therefore, in the principles of rehabilitation, the definition of training should be compatible with the daily functional needs of patients [8].

Which is beneficial in facilitating the execution of the patients' daily activities. Furthermore, according to the evidence, training specific movements can be helpful in recovering the motor function, which can be executed through implementing neuroplasticity adjustment [9].

Therefore, repeating these exercises the increases patient's functions [10].

In these articles, the plasticity was evaluated using Functional Magnetic Resonance Imaging (fMRI). Besides, the environment of execution of the process is crucial in rehabilitation after a brain stroke [11].

The environment that provides more possibility for motivation and physical activity is an enriched environment [12].

A variety of approaches have been suggested regarding motor rehabilitation in brain lesion and stroke patients, the role of which has been proven in the neuroplasticity changes [14].

including moving the paralyzed limb and keeping the healthy limb still [15]. The results indicated that the size of paralyzed limb increases after executing the exercises [12].

Furthermore, according to the MRI images, the gray matter in the sensory-motor cortex grows in size after conducting these exercises. Therefore, there is sufficient evidence regarding the physiological and structural changes in the patient's brain (plasticity) after performing the exercises of movement therapy on the basis of imposing the restriction. Another approach is to use a rehabilitation robot, which can help patients during the movement and resist that movement [13].

Besides, these robots can provide qualitative and appropriate measurements of the function of the human subjects. The important issue in utilizing the rehabilitation robot is the control of the delay caused by the time of entry and exit of signal in the muscle-nerve tape or location signal at -, which is used in the robot's feedback path. The reduction of this delay time is crucial since it facilitates the concurrency between the sensory and motor data in the neuroplasticity process.

The plasticity evaluation in this method can be carried out using transcranial magnetic stimulation (TMS). Performing the rehabilitation exercises and movements has an indirect effect on neuroplasticity. However, utilizing the external current stimulation through functional current stimulation by adding the power of afferent inputs, can directly facilitate the process of plasticity adjustment. Furthermore, using the feedback of several sensors can have a crucial role in motor learning through the motor-sensory loop, which is damaged due to stroke. Different approaches were suggested regarding the use of feedback of several sensors including training through watching the respective movement performed by another person, training using virtual reality, and brain-computer interface (BCI) technology. In all of the aforementioned items, the impact of feedback of the respective sensor in the process of motor learning and neuroplasticity changes of brain is approved [11].

In general, the process of learning motor activities can be divided into five diverse phases. The first phase is the fast learning stage (initial), in which a considerable change occurs in the progress of a person's performance during the exercise stage.

The second phase is the slow learning stage (secondary), in which progress is achieved during the exercise stages. The third phase is the stage of stabilization, in which spontaneous progress will occur in a person's performance. This process occurs after the passage of 4 to 6 hours after the first exercises and without the extra practice of the activity. The fourth phase is called the automatic stage during which the learned activity requires less cognitive resources and is strengthened through the passage of time and the conducted interventions.

Finally, the fifth phase is called the memory stage. In this stage, the motor skill can be easily carried out after the passage of a great amount of time and without any further practice. Using the applied imaging method, the extent of the active neural network in this type of learning can be identified. Besides, the changes and plasticity of the neural networks can be identified properly on account of acquiring the skills in the motor activities due to the exercise. A variety of studies on animals and humans demonstrated that various structures of the brain that constitute cortico-striatal or cortico-cerebral anatomic systems are necessary for learning and performing motor skills and acquiring various phases of learning [14].

Accordingly, it appears that there is a relationship between the in task space and motor execution level. The importance of this issue is that no changes occur neither in the motor cognitive description, nor its description in the external space on account of any disruption in the central nervous system (CNS). For instance, in the motor cortex of the brain, the problems occur in the control level and execution of the control commands [26].

On the other hand, changes occur in the conventional application of muscles and weighting muscle synergies. Muscle synergies are defined as a model of cooperation of muscular activities in a specific collection of muscles. Consequently, controlling the combination manner of the synergies provides the possibility of controlling and performing different movements and facilitates the control process [15].

The main challenge in this regard is determining the muscular synergies. We are of the opinion that not only do synergies consider the control commands, but also they are defined with respect to the conditions of movement and the physical space of movement. Therefore, there should be a relationship between describing a movement in the space of action and performance [15].

The present research sought to investigate this theory. It should be noted that disruptions in the central nervous system (CNS) do not cause any changes in the cognitive description and the action space. However, the inability to carry out a task appears in the level of control and executing the control commands such that changes in unconventional use of muscles and weighting muscular synergy is obvious.

Overduin *et al.* investigated the modulation manner of muscle synergies in performing the movement of grabbing by hand. They stated that considering that muscle synergies are in fact predetermined and unchangeable patterns of muscle activity among them, the synergies can be used as units that their linear combination can result in the formation of expansive arrangements of muscular patterns, taking into account the appropriate weighting and temporal coefficients.

Therefore, in case the manner of application and control of muscle synergies can be analyzed in relation to the motion space and its type. A quantitative criterion can be defined to be used in evaluating the CNS performance and increase the speed of learning by performing appropriate exercises. Cheung *et al.* compared synergy in healthy people and those suffering from brain stroke regarding the arm reaching movements. They demonstrated that synergies do not undergo any changes during brain damage and a person's inability in performing hand movements is related to the incorrect simulation coefficient of synergies since they are pertinent to the spinal cord.

This conclusion was great progress in orienting and accelerating the rehabilitation of patients with a brain lesion. Using fixed synergies during rehabilitation can help to diagnose the damage coefficient and orient rehabilitation strategies to correct them.

Safavynia *et al.* introduced synergy as a criterion for evaluating the motor performance of the nervous system in human body. They empathized that muscle synergy analysis in patients and even healthy people can provide execution accuracy not only in the external coordinates and performance of limbs, but also in the process of employing muscle synergy in human nervous system.

According to the studies in the field of controlling movements in animals and humans, Byadarhaly *et al.* concluded that using the synergies combination as a control module is more appropriate than the standard feedback control methods on the basis of constant follow-up of the proper path.

d'Avella *et al.* studied the impact of muscle synergies in human arm movements in eight different orientations and the impact of neuroplasticity. This research analyzed the impact of variation by time, besides the speed of movement in synergies. Therefore, they manifested that in case analyzing the manner of application and controlling the muscle synergies in relation to the movement space and its type, it might be possible to evaluate the performance manner of the CNS, and increase the speed of motor learning in patients (e.g., patients after a brain stroke) by performing the appropriate exercises, which is related to the neuroplasticity characteristic of the brain. According to the investigations, by increasing the motor recovery, the extent of active areas decreases. Therefore, it can be concluded that after a stroke, expansive areas of the brain are activated due a motor activity, the extent of which decreases over time and by the recovery increase. No linear increase or decrease was observed in the amount of activity of the brain areas due to motor activity in none of the participants of control group.

Discussion

Muscle synergies (Figure 3) invaritation due to brain stroke is among the important subjects that should be taken into account in the rehabilitation of these patients.

One of the factors that lead to the increase of the complexity of descending motor activities is that the motor areas of the cerebral cortex should orient a great number of activities of muscles enjoying thousands of movement units in every body part for even the simplest movements.

Probably the CNS deals with these complexities by movement control strategies. This system dominates over the movement control complexities using the linear combination of motor synergies, each of which activates a group of muscles.

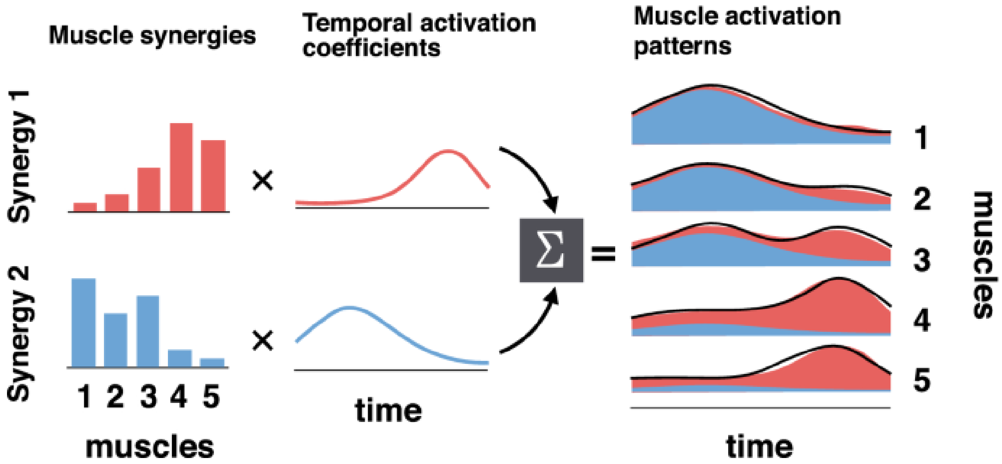

Figure 3 Muscle synergies

Cheung *et al.* investigated the assumption that muscle synergies are determined by the neural networks of the spinal cord, or brainstem, and the cerebral motor cortex is responsible for selecting and activating them. To provide a response to this question, records were taken from the muscles of brain stroke patients with a lesion in the frontal lobe, which caused serious disruptions in their motor activities.

Therefore, they recorded the signals of muscles of arms and shoulders of both arms of eight brain stroke patients with limited lesions and, in some cases, with severe lesions in the frontal lobe, plus six healthy participants of the control group.

According to the observations, in most patients, there was a similarity between the muscle synergies pertinent to arms affected by brain stroke and the healthy arms.

Despite the similarity between synergies of both arms in patients, the recorded signals of two arms were quite different. These differences indicated the motor disability of arms affected by a brain stroke.

Furthermore, by comparing the synergies from the patients and healthy participants, it was revealed that there was great compatibility between them. In accordance with the results, the structure of these synergies is probably developed by the intermediary nervous circuits pertinent to the spinal cord or neurons inside the brainstem. On the other hand, with respect to the results, the damages caused by the stroke led to motor disabilities by making intervention in the manner of activating the synergies.

Accordingly, emphasizing the muscle synergies whose pattern of activities have been changed after a stroke can be used for rehabilitating people suffering from a brain stroke [38,39].

Modular control is one of the interesting hypotheses in the field of motor control. In this hypothesis, a number of motor bases are considered as the constructing units and the collection of various movements is the result of diverse combinations of these motor units. Motor modules provide a powerful framework for removing the current restrictions in development of the effective rehabilitation treatments for individuals. Extracted modules are different in various individuals and with respect to the type of neurological lesions. Motor modules are configured on the basis of the number and the pattern of muscle synergies in the adjustment process. After neural damage, these modules, also known as muscle synergies, change their coefficient of employment.

In case the damage to cerebral cortex causes a negative effect on the employment and the combination of structured synergies, providing feedback of the inaccurate performance of synergies' activation coefficients, in these cases the time of recovery after various disruptions can be decrease. The researchers could not find out how the CNS faces a flexible and stable motor control complexity. Currently, the studies emphasize the efforts for maximizing the chances of neuroplasticity in the cerebral cortex to provide more potential to achieve success in the rehabilitation treatments for neural disorders. Recent studies demonstrated that using non-aggressive modulation of the cerebral cortex can have an ever-lasting impact on the plasticity of cerebra cortex. A variety of studies indicated that these techniques can be used as a new treatment for disparate neural disorders and they can be considered as an emerging strategy in the rehabilitation of neurons by increase neuroplasticity. Even though the present article merely discussed the aspect pertinent to the neuromotor control processes, the neuromotor recovery analysis is the initial valuable step in analyzing motor skills in general. More studies should be conducted regarding the unknown mechanisms of motor modules to discover the manner in which the motor modules are transferred by the specific nervous structures and neuromechanical interactions.

Conclusion

The process of neuromotor rehabilitation of patients with brain lesions and skills development in them compared to healthy individuals by analyzing the degree of plasticity is an effective way to strengthen muscles and can be effective. However, further investigation is needed.

Limitations and Suggestions for Further Research

Lack of access to the text of articles published in different languages, lack of access to the results of dissertations, and also the low quality of some articles were the limitations of this study. However, it is recommended that neuromotor rehabilitation be performed for patients with stroke.

Conflict of Interest

The authors declare that they have no conflict of interest

Consent for Publications

All authors agree to have read the manuscript and authorize the publication of the final version of the manuscript

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