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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.

GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.

ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ, რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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NEUROPLASTICITY AND BRAIN STIMULATION: DEVELOPING INTERVENTIONS TO PROMOTE RECOVERY FROM STROKE AND TRAUMATIC BRAIN INJURY

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Abstract.

This article's purpose is to explore how "non-invasive brain stimulation" (NBS) can be used to treat "traumatic brain injury" (TBI) and promote neuroplasticity. Along with the pathophysiological processes that occur after a TBI, "transcranial direct current stimulation" (tDCS) and "transcranial magnetic stimulation" (TMS) are described. These processes are based on a study of the relevant literature. Individualized treatment plans are required because the pathophysiological processes that result from TBI change over time. Given their neurophysiological effects, TMS and tDCS may be used to (a) significant suppression of post-traumatic cerebral hyper excitability; (b) control synaptic plasticity over the long run to prevent unfavorable outcomes; and (c) in addition to other forms of treatment such as physical and behavioral, assist some neural networks to reorganize and consolidate their learning. These treatments have the potential to reduce the disabling symptoms of brain injury.Animal and human research show that NBS may help reduce the severity of injuries and increase plastic changes in lesioned brain tissue, both of which are necessary for the successful acquisition of new knowledge and the restoration of lost functions. However, at present, this evidence is mostly speculative. The relevance of NBS in TBI, further elucidating its therapeutic benefits, and defining appropriate stimulation levels all need investigations in TBI patients due to safety concerns.

Key words. Neuroplasticity, transcranial magnetic stimulation (TMS), traumatic brain injury (TBI), transcranial direct current stimulation (tDCS), non-invasive brain stimulation (NBS).

Introduction.

The capacity of the brain to modify and adapt during a person's life is referred to as neuroplasticity. In response to experiences, learning, and environmental changes, the brain can reorganize its connections, structure, and functions. Because of neuroplasticity, the brain may create new neural connections, alter existing ones, and even transfer certain tasks to other parts of the brain. Brain stimulation entails the use of different methods or treatments to influence the activity and function of the brain either directly or indirectly. It seeks to modify or intensify neuronal activity in the brain to encourage desirable changes. Techniques for brain stimulation may be used either internally or externally, and they can target certain networks or parts of the brain. Deep brain stimulation (DBS), tDCS, TMS, and electrical stimulation are some of the methods of brain stimulation that are often employed [1]. Enhanced understanding and acceptance of the brain's natural adaptability to its circumstances, as well as one reduction in to restrictions provided by the idea of localization, have led to the emergence of potential treatment applications of neuroplasticity to improve function results following brain injury. The introduction of electro-physiological mapping of the brain, which has shown reorganization in response to training both before and after damage, has been a major contributor to this progress. Thanks to improvements in functional and structural testing, as well as neural mapping, experts now had a greater understanding of brain interconnections and complex of the brain. Understanding the functions of the synapse, dendritic sprouting, neurotrophic drugs, and individual genetics in neural remodeling, neurogenesis, and function recovery is progressing. As a consequence, treatment strategies may now be developed to boost neuroplasticity and improve prognosis after all forms of acquired brain damage [2]. The brain may change its synaptic connections for better or worse, depending on the circumstances through experience and stimulation. The impact of enriched settings on brain development was eventually discovered as a consequence of their expansion of the idea and description of use-induced plasticity of the nervous system, marking a new area in brain research. The ability for activity-driven synaptic strength changes and the extensive network architecture of the cerebral cortex gives rise to plasticity [3]. The term neuroplasticity is used to describe the brain's capacity for structural and functional plasticity in response to learning, experience, and environmental factors. The brain's ability to make new neural connections, reinforce old ones, and redistribute cognitive tasks is a defining characteristic. Learning, memory, and healing from neurological diseases including stroke and TBI are all aided by neuroplasticity. Brain injuries like strokes and concussions may cause permanent disability or the inability to perform certain tasks. However, neuroplasticity suggests that the brain may make up for these deficiencies and recover. Those who have had a stroke or TBI may benefit from brain stimulation treatments, which are therapies that harness and increase neuroplasticity to hasten healing and rehabilitation [4]. A stroke or TBI is a medical emergency that can have far-reaching consequences for the victim and their valued ones. The resulting physical, mental, and emotional problems often necessitate prolonged treatment and care. Although getting better can be difficult, new treatments and ways of thinking about the brain's resilience have opened up promising avenues for improving survivors' chances of doing so and living fulfilling lives after the trauma. T examine the many approaches and interventions that help people recover after

suffering a stroke or TBI. This all-encompassing strategy aims to maximize outcomes and help survivors to regain independence and engage actively in their lives by addressing not only physical and cognitive but also emotional and psychological well-being [5].

The study [6] discussed the importance of neurotrophic factors and receptors following TBI in zebrafish and humans, as well as the optimal timing to intervene. TBI continues to be the largest cause of long-term disability, affecting millions of people worldwide every year. Neurotrophins have been the subject of many mammalian studies that suggest they may play an important role in the prevention and rehabilitation of neurological damage. Article [7] provided a synopsis of the present state of the research as it relates to neurorehabilitation and to help individuals interested in the background of these ongoing clinical studies. Some of the most common causes of impairment include strokes and TBIs. The study [8] examined the inflammatory processes and behavioral abnormalities associated with TBI and analyzed the current and prospective novel treatment options for managing these conditions. Despite rehabilitation efforts, over half of the individuals who suffer from severe TBI and need hospitalization still have significant disabilities. Hemorrhage, widespread axonal harm, and injuries are just a few examples of tissue damage that may result from TBI. Executive functions, cognitive level, attention, memory data processing, and language skills are often negatively impacted by TBI. The article [9] provided a concise overview of recent advances in cell-based treatments and the use of bioactive matrices, including hydrogels, in regenerative medicine approaches. In this article, they examine the features of bioactive matrices that have been found to improve brain healing in TBI models. The paper [10] injected hADSC-derived exosomes (hADSC-ex) into the rat brains using a weight-drop-induced TBI paradigm. The research shows that administration of hADSC-ex to rats with TBI improves functional recovery, decreases Neuroinflammation, prevents neuronal death, and boosts neurogenesis. In terms of therapeutic efficacy, hADSC-ex was on par with hADSC. The study [11] examined the role of various stem cells in TBI and discussed their impacts, deficits, and associated processes. TBIs are a leading cause of death and disability worldwide because of the severe neurological damage they may inflict. The study [12] investigated how suppressing Histone deacetylase (HDAC) would impact BDNF production and functional recovery in mice with traumatic brain injury. Movement, sensory, and cognitive impairments are all frequent results of brain trauma. HDAC inhibitors have been shown to have neuroprotective benefits against many types of central nervous system (CNS) injuries, and this data continues to mount. The research [13] investigated the effectiveness of elements as a virtual rehabilitation technique for stroke sufferers. Virtual reality systems have the potential to be useful tools for neurotrauma recovery. Strong therapy effects are produced for upper-limb and cognitive function following TBI by the elements system, which uses customized surface computing and physical interfaces. The study [14] investigated how aging affected the cerebral metabolic mechanism of electro-acupuncture to provide fresh support for the creation of age-appropriate rehabilitation techniques. Age has a significant impact on the clinical effects of treating cerebrovascular illnesses, and there is evidence that these effects may be related to age-related changes in neural plasticity. Electro acupuncture is a powerful substitute therapy for TBI. The paper [15] provided particularly problematic for dementia or secondary age-related cognitive impairment after a TBI. Even though there are probably several different biological mechanisms at play, an increasing amount of research shows that cerebral microvascular disease is a widespread endophenotype throughout the range of TBI severity. The study [16] looked at the possible regulation protective mechanism of bone mesenchymal stem cells exosomes in reducing Neuroinflammation in the initial days following TBI. Globally, TBI ranks among the top 10 causes of death and disability. Despite the existence of treatment guidelines, there is currently no ideal therapy or medication for this illness. In order to establish the framework for recognizing the logic of employing NBS to reduce harm and aid in recovery, this paper discusses the acute and long-term processes of TBI. Figure 1 shows the function of the recovery from stroke and TBI.

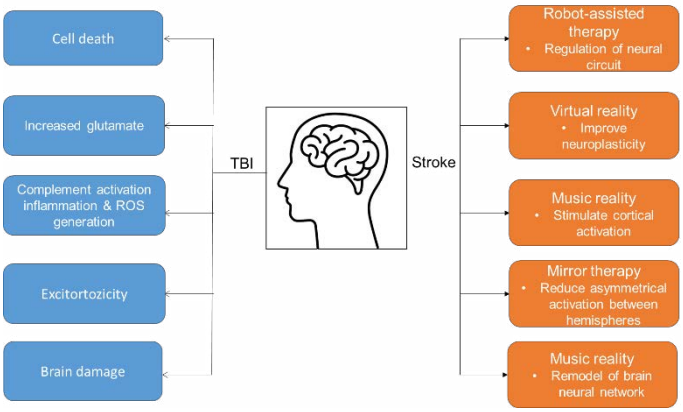

Figure 1. *Processes of TBI and Stroke Disruption.*

Chronic changes following TBI: Subacute Changes.

The Effect of TBI on Brain Plasticity.

Systemic reconfiguration may occur at all stages throughout the body, from the molecule and cells to the anatomical and behavioral, as a consequence of a shift in the neural network's efferent requirements or afferent input. This is known as plasticity, which is a persistent, intrinsic trait of the nervous system. The reaction to injury to the peripheral or CNS, as well as neuronal growth and homeostasis, are all impacted by this dynamic process. Plasticity can be seen as a way for the brain to recover from injury and resume normal function in the context of brain damage. There are three phases to the recovery of function following a TBI. After brain damage, the first stage is for healing mechanisms to be activated, which causes the reduction of edema and inflammation and primarily occurs within the first three weeks. In the second phase, additional links are formed anatomically while functional cell plasticity alters the characteristics of pre-existing neural networks. The first three months following the shock are when plasticity and remyelination become most noticeable, making them the most crucial elements after the acute stage. As a result, acute and

subacute settings are where patients recover the most. Figure 2 shows the functional recovery in patients with TBI and Stroke.

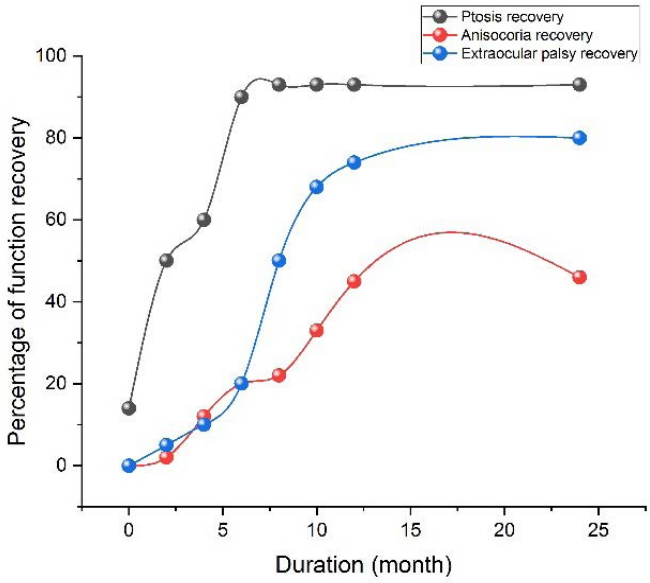

Figure 2. *Recovery from TBI and Stroke.*

Subacute Period.

The second phase of functional recovery following brain injury is called operational cellular plasticity, and it refers to temporary but potentially rapid changes in brain structure and function. During that point, the inflammation and swelling should have decreased. Short-term plasticity relies heavily on modifications to the degree of excitement or inhibition brought about by alterations in neuronal traffic, the fastest of these processes. These modifications cause a reduction in the tonic inhibition mediated by γ-aminobutyric acid (GABA) interneurons, allowing neuronal networks to become active. Animal studies have shown that TBI results in memory retention problems that persist for about a month after the initial lesion. The chemical glutamate acid decarboxylase, which transforms glutamine into GABA, is produced in greater quantities concurrently with this procedure, and inhibiting its activity prevents this transition from occurring. These results suggest that an excess of inhibition generated by GABA may contribute to impairments similar to those seen in the subacute period after injury. One fast process for brain plasticity is when the strength of individual synaptic changes. Action potentials directed at the presynaptic membrane can either increase or decrease postsynaptic activity and repeated neuronal activity can alter these aspects of synaptic transmission. As a result, during the process of encoding new memories, specific synapses are activated, resulting in increased synaptic strength. Direct recovery implications include aiding healing from brain injury and enhancing memory and learning, both of which are facilitated by activity-dependent synaptic plasticity. Extensive research in both healthy and brain-injured animal models has shown that regular exercise has profound impacts on synaptic activity, leading to substantial gains in areas such as object identification, spatial learning, and motor skill development. Similar findings have been seen in human research which has investigated brain injury, which may have significant consequences for neuromuscular and cognitive recovery. To make the most of activity-dependent plasticity for behavioral gains over recovery, it is crucial to comprehend the components connected with plasticity. The dentate gyrus was the brain region where Long-Term Potentiation (LTP) was initially identified, followed by the motor cortex. Long-lasting enhancement of the strength of excitatory glutamatergic synapses following transient high-frequency stimulation is the phenomenon under question. That is, it causes a long-lasting impact after a stimulus that, under normal conditions, would only provide a transient effect followed by a speedy return to baseline. The ability to generate modifications to a particular group of synaptic within a cell without affecting other synaptic explains why LTP is so essential. Specifically, LTP can be generated in one set of synapses within a neuron without impacting any other synapses in the cell. Together, Long-Term Depression (LTD) and N-methyl-D-aspartate (NMDA) receptors play crucial roles in these cognitive processes. Several factors outside of synaptic history and learning have been demonstrated to affect LTP and LTD. These include development, aging, stress, disease, and brain injury. TBI can have varying effects on LTP and LTD. The occurrence of Late Posttraumatic Seizures (LPTS) following TBI is well-documented; it ranges from 5.9% in civilians to 32.5-50% in military personnel. Seizures could result from hyper excitability caused by an abundance of LTP at glutamatergic synapses under these conditions. However, GABA-mediated inhibition following single and recurrent concussive injuries has been demonstrated to continuously suppress LTP and LTD in humans, leading to long-term motor and cognitive impairments.

Chronic Changes.

LTP and LTD are both seen as transitional processes that may be enhanced afterward by structural alterations. In humans, the ipsilateral brain is the primary site of these alterations, with the contralateral brain involved in extreme instances of injury. When these procedures are carried out, a more durable and safe plastic transformation is certain to take place. Microscopically and macroscopically, one might see evidence of these structural alterations. Memory loss after brain injury is often attributed to damage to the dentate gyrus of the hippocampi, which may occur even with moderate TBI.

Maladaptive Plasticity *vs.* Adaptive.

Although plasticity plays a significant role in facilitating recovery from brain damage, the resulting alterations can sometimes be beneficial and may have negative consequences. Examples of pathological plastic alterations include spasticity after a stroke, chronic pain, schizophrenia, and dystonia. Such maladaptive plasticity after TBI might lead to impaired motor and cognitive recovery, and perhaps the onset of Alzheimer's disease in certain patients. Seizures may begin in one area of the brain and spread to other, synoptically related areas if this process, known as collateral sprouting, occurs. In the case of the group diagnosed with a stroke, the following finger coincides with the group diagnosed with traumatic brain damage, as seen in Figure 3.

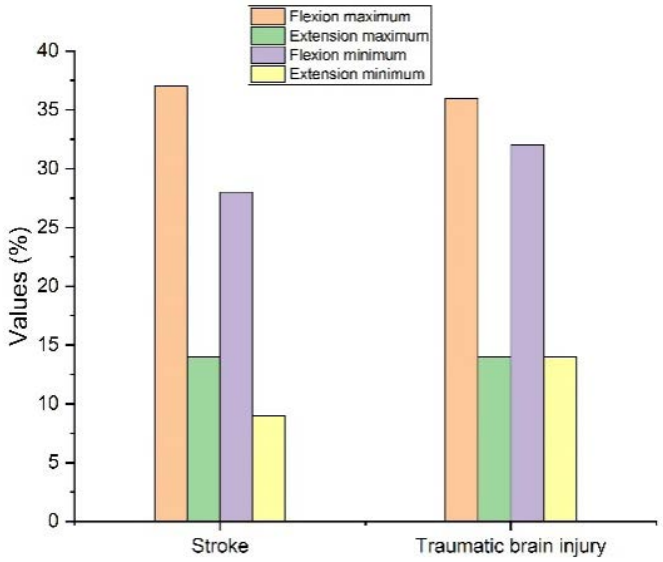

Figure 3. *Flexo-extension maximum and a minimum of treatments in TBI and stroke.*

Physiologic Effects of NBS.

Transcranial Magnetic Stimulation (TMS).

TMS is an NBS method that uses electromagnetic induction and was first used in 1985. Researchers have discovered that a long-lasting and considerable electric current sent through a coil placed across the head is required to produce a rapidly altering magnetic field, thereby setting off electrical impulses in certain brain areas. The electric current generated by a single TMS pulse may be strong enough to cause depolarization of cortical neurons, either directly by acting on the neuron's axon hillock or indirectly by depolarizing the neuron's neighboring interneurons. Multiple groups of neurons, mostly in the neocortex, may be concurrently activated by the generated electrical stimuli, some of which extend axons to or from the stimulation point. As a result, different effects may be created by synaptic dispersion on the cerebral cortex and in brain areas with similar functions. The effects of TMS are influenced by variables including coil orientation and baseline cortical activity, as well as patient-specific variables like morphological or neurophysiologic abnormalities. In animal models of brain damage caused by strokes in the cortical regions, the spread of energy becomes erratic and the highest level of current is localized over the boundaries of the lesion due to the effects of multiple sclerosis.

Long-Term Physiologic Effects of rTMS.

The inhibitory or facilitator properties of rTMS may be seen following a duration of stimulation that typically runs up to 15 minutes, and they typically linger for approximately ten more seconds after the treatment is complete. Although these benefits might last for many weeks, they are stronger with frequent discussions. Given their ability to demonstrate that rTMS are capable of creating an environment that is favorable to neuronal plasticity, the Potential therapeutic use of this strategy may depend on the strategy's ability to provide long-lasting effects following repeated application. These genes are promising possibilities for the long-lasting benefits of this NBS technology because of rTMS's potential to modify immediately early gene induction connected with neuronal activity and neurotrophic factors. After extended stimulation, the starting condition is more strongly produced, and neither reactive gliosis nor cell damage has occurred.

Short-Term Physiologic Effects of rTMS.

The rTMS is a method that uses trains of these electrical impulses to induce neural activity. Conventional rTMS occurs when pulses are delivered at regular intervals, whereas patterned rTMS consists of brief periods of intense stimulation separated by periods of rest. Quadripulse stimulation and theta burst TBS are two examples of programmed rTMS. Depending on the rTMS settings employed, a specific subset of neurons may be activated by electrical stimulation since their thresholds to this stimulation vary. Frequencies of ≥5 Hz exhibit the opposite impact of the more common frequencies of 0.2 to 1 Hz, which typically reduce excitability in the brain by inhibiting activity in GABAergic neurons. When a low-frequency pulse is followed by brief high-frequency maintenance respiration, the inhibitory effect of the low-frequency stroke may be enhanced. The short-term effects of stimulation seem to be mediated by variations in brain activity caused by ionic alterations near neurons in activity or by the treatment-induced recollection of energy. The electrical charge that is held on both sides of the cell membrane is altered by the electric field that is created in the brain tissue, leading to depolarization or hyperpolarization of the neurons. Reafferent feedback from the target structures to the stimulation site may be crucial. TMS predominantly affects cell fiber bends, axonal-soma, and axonal-bouton borders.

Transcranial Direct Current Stimulation (tDCS).

More than 200 years ago, the first currents of electricity used to alter brain function were documented. In the 1950s and 1960s, substantial animal models were used in these studies. Based on these findings, the NBS method known as tDCS was created. An inadequate direct current is transmitted from the anode to the cathode by attaching two big rubber electrodes to the skull. Even if electrical is switched on during off in their nearby tissues, the electronic inputs as reaches their brains was powerful sufficient can change the amount of spontaneous excitability in neurons and activity by changing the membranes voltage at resting. In contrast to neurostimulation methods like TMS that may induce action potentials by rapidly depolarizing the neuronal membrane, tDCS acts as a neuromodulator NBS treatment. Current intensities between 1 and 2 mA, particularly frequently operating for 10 to 20 min, are typical tDCS settings. The effectiveness of tDCS in producing acute alterations to membrane polarity is determined by current density, which is the product of current intensity and electrode size. While tDCS-induced responsiveness alterations during stimulation and afterward have comparable neurophysiologic effects, they are caused by different processes. They will be addressed individually as a result.

Long-Term Physiologic Effects of tDCS.

Alterations in the role of neuronal membranes, which do not involve synaptic communication, are also hypothesized as a

basis for tDCS's aftereffects. Contact with persistent electrical fields, such as those experienced during stimulation, may elicit ionic alterations and alterations in transmembrane proteins, resulting in enduring modifications to the function of brain membranes. However, synaptic pathways may potentially perform a part in the development of tDCS's aftereffects, in contrast to its immediate effects.

Short-Term Physiologic Effects of tDCS.

Human studies show that tDCS of the main sensory and vision cortex alters the excitability of the cortex in a polarity-dependent way, with anodal stimulating increasing cortex excitation and cathodal stimulation decreasing it. Changes in the excitability of the cortex caused by tDCS seem to persist more extensively than those induced by standard rTMS when administered for long enough. The beneficial effects of tDCS may be felt for weeks after treatment, and it only takes 13 minutes for a single session to alter cortical excitability for around 90 minutes. Figure 4 depicts the frequency distribution of patients based on their recovery score. To discover the shape of the curve that best reflects the recovery over time given in Table 1, the unconditional simulation was then run separately with the sequential additions of time, quadratic time, and cubic period. The findings indicated that a quadratic trajectory fit the over time the best.

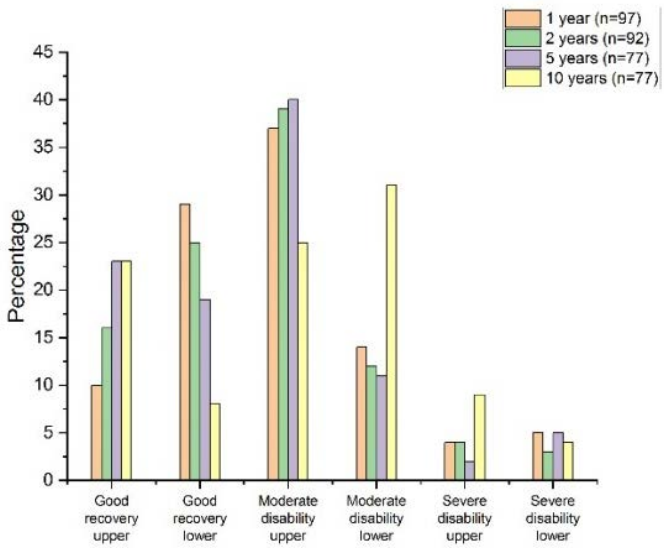

Figure 4. *Recovery Score Distribution.*

Table 1. *Trajectory of patient recovery.*

Model	**-2 log**
Cubic	1023.97
Quartic	1024.21*
Unconditional growth model	1048.63

Note: The necessary value of χ2 for a substantial difference at α = .05 is a decline from the prior model of ≥ 3.841.

NBS as a Therapeutic Tool in TBI.

Several neurobehavioral effects from TBI may manifest within days of the injury and continue to manifest over months. Seizures, headaches, movement disorders, motor impairment, linguistic and visual deficiencies, insomnia, memory, attention difficulties, and concentration problems are a few of these that may be present. The healing process is complicated, and it may take months or years to fully recover from these sequelae. In some cases, a full restoration to baseline function is not possible. The many pathways that cause TBI problems provide a window for certain therapies at various times. There are two main categories of strategies for addressing the effects of TBI; initially, they targeted reducing the severity of the first trauma to prevent additional neurological nature shortages; and minutely, those that encourage reorganization of neural networks, permitting for the revisiting of operates that were previously impaired or lost. Changing brain excitability for a sufficient amount of time is a viable therapeutic approach in this situation, which may help to a) mitigate the rapid inflammatory response to traumatic brain injury; b) influence the adaptive organization in a way that facilitates the development of structurally and functionally suitable neuronal connections; and c) promote behavioral healing.

Following a TBI, this discussion will go on to the theoretical underpinnings of NBS's potential therapeutic use. However, it should be highlighted that the following suggestions ought to only be utilized to stimulate further study in this area since there are not many papers addressing this subject and because the processes behind TBI are not fully understood. Most of the variable effects that were obtained from the whole HLM are shown in Table 2, along with their corresponding b-weights, p-values, and 95% confidence intervals.

Table 2. *Socioeconomic and demographic factors, plus injury predictors.*

	SE	**b-weight**	**95% confidence interval**		**p-value**
			Lower bound	Upper bound	
Intercept	.24	5.91**	6.46	7.36	<.0002
Time	.07	.017**	.05	1.27	.008
Occupation type	.04	.44*	.09	.79	.015
Relationship status	.22	.15	-.25	.54	.476
Education	.22	.06	-.16	.26	.620
Employment	.18	.52*	.12	.92	.013
CT severity score	.01	-.14	-.29	.03	.085
Cause of injury	.01	-.30	-.64	.07	.100
Glasgow coma scale score	.18	.02	-.04	.09	.385
Post-traumatic amnesia	.09	-.04**	.03	.01	.005
Injury severity score	.02	-.02	-.03	.02	.406
Time*time		-.03***	-.04	−.02	<.0002
Sex	.19	-.46*	-.83	−.11	.014
Age	.01	-02*	-.05	−.02	.013

Source: Author

Acute Injury.

They showed that getting well and learning new things after a TBI takes time. Consequently, treatment measures must be

carefully tailored to the prevailing pathophysiological pathways at each stage. Therefore, the methods and environments used to treat brain injuries must be carefully tailored to each patient. Acute treatment might benefit from therapies that reduce cortical excitability, such as those used to reduce excessive glutamatergic activity. Animal studies have shown that rTMS may reverse indicators indicative of oxidative stress as well as apoptosis after brain injury, suggesting that NBS may help in healthily healing inflammation and lowering the level of damage to the brain currently happening after TBI. However, since most NBS methods are quite specific, it is possible that they will not be as effective in the context of the broad phenomenon that is TBI. More studies using animal models are needed to better understand the efficacy of this approach. The neurological disruption and potential increase in stimulation of neuron elements caused by rTMS, even in the rTMS protocols connected to a decrease in cortex excitement, may be deleterious. Since tDCS is a kind of subthreshold stimulation, it would be a better fit for this situation. NBS may have little effect on lowering acute inflammatory processes, but it might help attenuate early plastic alterations that could have negative implications. There is an opportunity for intervention merely days after brain damage, as shown by animal studies showing robust axonal sprouting and synaptogenesis. Both Contralateral Thalamic Stimulation (cTBS) and Ipsilateral Thalamic Stimulation (iTBS) have been shown to have a positive therapeutic effect on patients with acute stroke by enhancing the excitability of the cortex in the injured brain.

Coupling NBS and Physical Therapy.

The CNS, the cerebral cortex, and the motor maps may all undergo plastic modifications as a result of mechanical instruction, including the acquisition of new abilities. These changes may include enhanced synaptic growth, LTD/LTP-like activities, and reconfiguration. Constraint-induced movement therapy (CIMT) has been shown to improve motor recovery in individuals with chronic stroke by altering representations of motor areas in the brain. Similar processes may explain why physical exercise improves motor and cognitive results in TBI patients. Most of what they know about using these therapies after TBI comes from research that focused on stroke rather than animals. Electrical cortex stimulation in conjunction with rehabilitation training has been demonstrated to improve functional outcomes after ischemic stroke in animal studies.

Subacute and Chronic Period.

Alterations in synapse strength and, eventually, morphological abnormalities, are necessary for inducing long-lasting effects on brain tissue. Modulation of LTP/LTD by NBS is a plausible therapeutic technique in the context of TBI since it may prevent or at least delay the development of such anatomical abnormalities. In addition, NBS has shown positive benefits in disease-specific contexts where it induces plastic alterations, such as in stroke. Chronic stroke patients who underwent glutamate stimulating to the lesioned boundaries of iTBS or anodal tDCS had the same positive results. Based on these findings, NBS may have therapeutic applications beyond mild TBI.

Positive and negative effects of NBS on neuroplasticity.

NBS's favorable effects on neuroplasticity.

• People who use NBS methods can enhance their cognitive abilities, including their memory, attention, and problem-solving capabilities.

• NBS may stimulate the brain to modify and improve its neural networks for optimal performance by giving actual time information regarding brain activity.

• NBS can be included in rehabilitation plans for those who have suffered brain injuries. By teaching the brain to make up for wasted functionality, it can assist in developing neuroplasticity and aid in the restoration of wasted abilities.

Neuroplasticity and Negative Effects of NBS

• Some NBS approaches' long-term effectiveness is currently being researched. In other situations, the advantages of NBS could not be long-lasting, disappointing and frustrating those looking for long-lasting enhancements in neuroplasticity.

• Some NBS techniques, especially those that include electrical or magnetic stimulation, can cause headaches, vertigo, and other unpleasant side effects.

• NBS methods that include seeing and modifying brain activity give rise to ethics and private issues.

Conclusion.

The complex structure of the pathophysiology that underlies TBI, the variety of symptoms that succeed at various periods, and the distinctive characteristics of every individual all call attention to the need of establishing individualized ways of treatment. They would assist the body in recovering and would lessen the intensity of any repercussions that may be disabling. Changes that appear both locally and distantly from the lesioned area are the result of brain plasticity, which takes place throughout the subclinical and chronic periods that follow an injury. Even while these modifications may help bring about functional recovery, they also carry the risk of bringing about more harm and undesirable results. To promote the former and repress the latter, it is essential to identify possible adaptive and maladaptive plastic alterations. Extensive research published over the last two decades has shown that rTMS and tDCS are very effective in inducing neuroplasticity changes in the brain. Other therapies, such as physical or behavioral therapy, may be combined with them to further enhance their therapeutic potential by focusing on even more particular brain networks. While these methods have shown promise in treating TBI, further work is required to determine whether or not they are safe and to determine the best way to stimulate the brain after an injury.

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Conflict of interest statement.

The author declares no conflict of interest.

REFERENCES

1. Boscutti A, De Figueiredo J.M, Razouq D, et al. Noninvasive Brain Stimulation Techniques for Treatment-

Resistant Depression: Transcranial Magnetic Stimulation and Transcranial Direct Current Stimulation. Psychiatr Clin North Am. 2023;46:307-329.
2. Nagappan P.G, Chen H, Wang D.Y. Neuroregeneration and plasticity: a review of the physiological mechanisms for achieving functional recovery postinjury. Military Medical Research. 2020;7:1-16.
3. Grovola M.R, von Reyn C, Loane D.J, et al. Understanding microglial responses in large animal models of traumatic brain injury: an underutilized resource for preclinical and translational research. Journal of Neuroinflammation. 2023;20:67.
4. Mishra A, Patni P, Hegde S, et al. Neuroplasticity and environment: A pharmacotherapeutic approach toward preclinical and clinical understanding. Current Opinion in Environmental Science & Health. 2021;19:100210.
5. Knutti K, BjörklundCarlstedt A, Clasen R, et al. Impacts of goal setting on engagement and rehabilitation outcomes following acquired brain injury: a systematic review of reviews. Disability and Rehabilitation. 2022;44:2581-2590.
6. Cacialli P. Neurotrophins time point intervention after traumatic brain injury: from zebrafish to human. International journal of molecular sciences. 2021;22:1585.
7. Khan S.M, Carter G.T, Aggarwal S.K, et al. Psychedelics for brain injury: a mini review. Frontiers in Neurology. 2021;12:685085.
8. Crupi R, Cordaro M, Cuzzocrea S, et al. Management of traumatic brain injury: from present to future. Antioxidants. 2020;9:297.
9. Tan H.X, Del Borgo M.P, Aguilar M.I, et al. The use of bioactive matrices in regenerative therapies for traumatic brain injury. Actabiomaterialia. 2020;102:1-12.
10. Chen Y, Li J, Ma B, et al. MSC-derived exosomes promote recovery from traumatic brain injury via microglia/macrophages in rat. Aging (Albany NY). 2020;12:18274.
11. Zhou Y, Shao A, Xu W, et al. Advance of stem cell treatment for traumatic brain injury. Frontiers in cellular neuroscience. 2019;13:301.
12. Sada N, Fujita Y, Mizuta N, et al. Inhibition of HDAC increases BDNF expression and promotes neuronal rewiring and functional recovery after brain injury. Cell Death & Disease. 2020;11:655.
13. Rogers J.M, Duckworth J, Middleton S, et al. Elements virtual rehabilitation improves motor, cognitive, and functional outcomes in adult stroke: evidence from a randomized controlled pilot study. Journal of neuroengineering and rehabilitation. 2019;16:1-13.
14. Huo B.B, Zheng M.X, Hua X.Y, et al. Effect of aging on the cerebral metabolic mechanism of electroacupuncture treatment in rats with traumatic brain injury. Frontiers in Neuroscience. 2023;17:1081515.
15. Swanson II R.L, Acharya N.K, Cifu D.X, et al. Cerebral microvascular pathology is a common endophenotype between traumatic brain injury, cardiovascular disease, and dementia: a hypothesis and review. Cureus. 2022;14.
16. Ni H, Yang S, Siaw-Debrah F, et al. Exosomes derived from bone mesenchymal stem cells ameliorate early inflammatory responses following traumatic brain injury. Frontiers in Neuroscience. 2019;13:14.