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The Influence of Diet and Physical Activity on Brain Repair and Neurosurgical Outcome

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Keywords

Omega-3 fatty acids; curcumin; exercise; neural regeneration; neurotrophin; cognition; synaptic plasticity

Introduction

The brain has a remarkable capacity for plasticity, an aptitude that ironically contrasts with the limited therapeutic approaches that would reduce the consequences of brain insults. Although a large amount of clinical trials have been performed to test the efficacy of various pharmacological compounds in minimizing the burden of neurological disorders, the results of many of these trials have been unsuccessful. Another concern frequently encountered in neurosurgical surroundings is that the patient outcome after brain surgery may not match the predicted prognosis. A likely explanation for these observations is that the intrinsic biological variability encountered in the human population can greatly influence the vulnerability of the brain to stress and insults. An increasing number of basic science studies indicate that environmental conditions and experiences encountered in the daily routine of individuals can dramatically affect the capacity of the brain to react to challenges. In particular, certain types of dietary factors, such as omega-3 fatty acids, can increase production of molecular systems that serve synaptic function, while diets rich in saturated fats do the opposite. In turn, exercise similarly displays healing effects on the human brain by counteracting the mental decline associated with age [11] and facilitating function recovery resulting from brain injury and disease [1, 6]. The overall evidence indicates that diet and exercise are two noninvasive approaches that can be used to improve molecular mechanisms of neural repair after brain surgery, most likely by working through brain-derived neurotrophic factor (BDNF). BDNF has been observed to play an important role in protecting neurons from insult and disease as well as modulating synaptic transmission [23]. As discussed below, studies have been conducted which indicate that select diets and cardiovascular exercise modulate levels of BDNF, thus affecting normal brain function and recovery events following brain insults.

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Diet

Omega-3 Fatty Acids, Vitamin E, Curcumin, and Caffeine

A number of studies point to the healthy effects of dietary factors on the brain. For example, fish-derived omega-3 fatty acids have been shown to improve cognition, plasticity, and recovery of neurons after traumatic brain injury. One of the most important forms of omega-3 fatty acids, docosahexaenoic acid (DHA), has been found to be a key component of neuronal membranes at sites of signal transduction at the synapse, suggesting that its action is vital to brain structure and function [10]. Evidence suggests that DHA serves to improve neuronal function by supporting synaptic membrane fluidity and function, and regulating gene expression and cell signaling [19]. Because the human body is not capable of producing its own DHA, supplementation of diet with foods rich in DHA is important in insuring proper function of neurons and in facilitating neuronal recovery after injury [25]. An additional benefit of omega-3 fatty acids which we observed in our studies is that they appear to reduce oxidative stress damage that results from trauma, indicating at the possibility of their application in assisting the recovery process [25, 26].

Another dietary supplement that has shown promise in protecting neurons is Vitamin E, found in certain oils, nuts, and spinach. Vitamin E functions as an antioxidant, reducing free radicals in the brain which would otherwise impede optimal function of neurons. Vitamin E has shown positive effects on memory performance in older people [17], indicating its ability to maintain neuronal health. A different study similarly revealed the benefits of Vitamin E by showing a correlation between the amount of ingested Vitamin E and improved neurological performance, survival, and brain mitochondrial function in aging mice [16].

Curcumin, a yellow curry spice, has also been suggested to enhance recovery events after brain trauma, displaying particular potency in preserving cognition. Curcumin was found to improve neuronal function in individuals afflicted with Alzheimer's disease by reducing oxidative stress and amyloid pathology [5]. In addition, it was found to protect the brain from lipid peroxidation [20] and nitric oxide-based radicals [21]. In accordance with these observations, our own studies have showed that the supplementation of curcumin into the diets of rats reduced the effects of experimental concussive injury on cognitive function tasks [27].

Studies observing the effects of caffeine on neuronal regeneration and function are recently emerging. A new study shows that chronic, but not acute, treatment with caffeine protects the brain against injury in animal models of Parkinson's disease and stroke by increasing glutamate release and inflammatory cytokine production [12].

Caloric Intake

Cognition and plasticity of the brain have also been shown to be affected by caloric intake and the frequency of food consumption. Restriction of calories seems to increase levels of BDNF, resulting in improved neuronal function. Fasting every other day has been shown to protect neurons in the hippocampus against excitotoxicity-induced death [2]. In the study, rats put on an every-other-day-fasting diet for 2-4 months had hippocampus neurons that were much more resistant to degeneration induced by kainic acid, and greater preserved memory than rats fed ad lib.

Saturated-Fat Diet

While certain foods seem to contribute positively to neuronal health, diets that are rich in saturated fats appear to decrease levels of BDNF in the brain and lead in poorer neuronal

performance. Molteni and colleagues have shown that rats fed a diet high in saturated fats and refined sugars (similar in content to the "junk food" that has become popular today) for a period of 1-2 months, performed significantly worse on the spatial learning mater maze test than rats fed a healthier diet that was low in fat and contained complex carbohydrates [13].

Exercise

Exercise Prior to Injury

Much like a healthy diet, physical activity is thought to benefit neuronal function by increasing BDNF levels and reducing oxidative stress. More specifically, exercise has been found to play an important role in the regulation of neurite development [30], maintenance of the synaptic structure [24], axonal elongation [15], and neurogenesis in the adult brain [22]. Studies have indicated that physical activity displays long-lasting changes in morphology and function of the nervous system, suggesting that a lifestyle which implements regular exercise can lead to a brain more resistant to insults. This hypothesis has been upheld in animal studies which indicate that exercise prior to brain trauma produces prophylactic effects on brain damage and limits the infarct size following forebrain ischemia [29]. Studies have also shown that pre-injury exercise has benefits in animal models of stroke [4] and Parkinson disease [3].

Exercise Following Injury

Post-injury application of exercise also seems promising in facilitating recovery, but more studies are needed to determine when and to what extent it should be integrated into a patient's lifestyle. When physical therapy was implemented to treat Parkinson disease, patients showed signs of increased motor ability [8]. However, when exercise was applied immediately following experimental traumatic brain injury, animals showed exaggerated effects of the injury [18]. The timing for the optimal application of exercise after injury is still controversial, as there is evidence from tests conducted on rats to believe that it can be counterproductive when applied during the acute injury phase [7].

Most Effective Form of Exercise: Cardiovascular Exercise

Not all forms of exercise show the same effects on brain cognition and synaptic plasticity. When the effects of treadmill running, swim training, and stand training were compared in injured rats, treadmill exercise was found to be the most effective in the recovery process [9]. These findings indicate that cardiovascular activity similar to running or walking is most closely tied to neuronal regeneration out of the three exercise methods studied.

Diet and Exercise: Combined Effects

When diet and exercise are combined, the success of regeneration and healing seems more pronounced than when either option is implemented by itself. Emerging studies indicate that exercise is capable of boosting the healthy effects of certain diets such as omega-3 fatty acids [28]. It has also been observed that exercise can counteract some of the deleterious effects of a saturated-fat diet on synaptic plasticity and cognitive function of rats [14].

Conclusion

Lifestyle conditions such as diet and exercise can contribute to the ability of the brain to counteract neurological disorders. Specific diets and exercise routines have been shown to impact select factors which can make the brain more resistant to damage, facilitate synaptic transmission, and improve cognitive abilities. Accordingly, managed dietary manipulations

and exercise have strong therapeutic potential. The overall evidence in the neural repair field indicates that this capacity could be implemented as a precondition to improve the outcome of brain surgery. Because diet and exercise are an integral part of human life, applying them to facilitate regeneration of neurons after injury or surgery would be a noninvasive and practical approach for enhancing recovery.

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