Treadmill Applications on the Neurophysiology of the Diseased and Elderly: A Review

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Abstract

Objective
To evaluate treadmill equipment and analyze therapeutic uses for exercise and fitness, thereby increasing brain and body protection.

Background
Review of the historical evolution of the treadmill and its contribution to medical care, aging adults, and potential outcomes of treadmill use. These outcomes have been associated with improved brain activity and increases in activities of daily living, thereby improving quality of life throughout the lifespan.

Material and Methods
Information about the treadmill system was gathered from literature, searches in books, journals, and PubMed on the use of the treadmill.

Discussion
The focus of the present article is the analysis of the treadmill, its beneficial health contributions and improvements in the neurophysiology of the diseased and elderly. The body's ability to create neuroprotective factors, improving with treadmill use, may be able to improve complications associated with Parkinson's disease, Alzheimer's disease, and memory during physical therapy with a neuromuscular disease. Cognitive changes associated with treadmill use and exercise also increase the quality of life of the elderly.

Conclusion
Exercise and fitness is a beneficial way to improve a variety of conditions, now being used as therapy of neurological diseases, with the theory that it can increase neuroprotective factors in the aging population. Along with the neurological benefits it can also aid in increasing independent living in the aging population.

Keywords: Treadmill; Fitness; Neuroprotective factors; Neurogenesis; Cognitive; Aging

Introduction
Treadmills have become one of the most widely used pieces of exercise and fitness equipment around the world over the last 40 years, with 51 million people using them in the United States today [1]. This type of equipment can be found in home gyms and fitness centers; they are used for personal and professional fitness training, spanning populations from young adults through the aging. The equipment has been used for exercise, fitness and rehabilitation, as well as in physical therapy, cardiovascular training, pulmonary and neurological disease, aiding in conditions such as Parkinson's disease, neuroplasticity, dementia and Alzheimer's disease [2].

Materials and Methods
Information about the treadmill system was gathered from literature, searches in books, journals, and PubMed on the use of the treadmill. Inclusion criteria for PubMed articles was from 2008 through current literature, with the primary focus being more recent than 2012. Inclusion criteria involved the key words; treadmill, aging, neuroprotective, Parkinson's disease, Alzheimer's disease, cognitive, and dementia. Articles that were reviewed included RCT and basic neuroscience studies.

Results and Discussion
The evolution of the treadmill shows a progression of uses throughout history. The first treadmills were originally used 4000 years ago in Egypt for the purpose of harnessing power created by the labor of both humans and animals [3]. Originally, they were called tread wheels and were used primarily to grind grains and to pump water, a common practice through the Roman Empire. Then, throughout the 1800's, farmers and potters in America used
animals to work these tread wheels to churn butter. In 1818, Cubitt came up with the notion to utilize these machines in prisons for punishment, but was hidden under the guise of rehabilitating prisoners while creating quality labor to grind grains and pump water. It was not until 1913 and 1930 that the early patents for the treadmill emerged [4,5]. Then, in 1952, the idea of using treadmills in the medical field for therapy and diagnosing cardiac and pulmonary functions became a standard, now known as the Bruce Protocol [6], used to determine exercise protocol for a user.

When treadmills began to be used in medicine it was in small number, then more widely used for fitness training as a piece of exercise equipment during the 1970’s and 1980’s. Today’s equipment is seen in numbers at rehabilitation and fitness centers, and is even more popular as an in-home item [7]. During this time, many alterations, upgrades and additions have been made due to cost, competition, modernization and bodily injury.

In the early stages of development the equipment was created to test users in the hospital for vital statistics of the heart and electrocardiogram diagnosis. These tests could see how the heart rate was affected during exercise as analyzed by the electrocardiogram diagnosis. In 2014 Lee et al reported a wearable electrocardiogram diagnosis devise that a user could wear as a chest belt and the information would be transmitted wirelessly for heart rate monitoring with a user on a treadmill [8]. Also, in 2015 Doa et al reported of advanced phonocardiograph signals to assist the physician by using a wireless laptop computer and collected the information with the use of a workout. This new technology shows how a treadmill and a computer can work together to help a user [9].

Treadmills can come with or without a cushion suspension system for support of the body to avoid foot or knee injury during training [10]. The machines can be flat with no incline or have various incline adjustments [11]. A conveyor split-belt system has two moving belts that can go at different speeds at the same time. This form of a moving belt can help a person who may have a walking impediment to be able to go onto a treadmill and walk at a therapeutic pace [12].

Physiological research has shown that while exercising the human physiology can affect many neurotransmitters and neurohormones. Exercise allows for improved modulation of leukotrienes to reduce levels of inflammation [13]. While exercising lung tissue can be remodeled after inflammation [14] and inflammatory mediators, such as tumor necrotic factor-α and interleukin-17, have also been identified to decrease [15,16]. Increased exercise may also decrease levels of nitric oxide, thereby having beneficial effects of the aging process and wound repair [15,17].

It has been hypothesized that treadmill training may mediate increased hippocampal perfusion. Hippocampal volumes increased with aerobic fitness, leading researchers to hypothesize that part of the neurocognitive benefits from aerobic exercise arise from this correlation [18]. Current research is trying to identify how exercise causes better perfusion, and it is believed that increased levels of brain-derived neurotrophic factor, vascular endothelial growth factor-C, and insulin-like growth factor play a role [19-21]. Other growth factors that respond by increasing number include fibroblast growth factors [22,23]. Along with these changes, this equipment may be associated with decreases in transforming growth factor [24]. With the introduction of daily exercise in the aging, some risk factors for diseases can be modified.

Gait is the manner or style that a person is walking naturally. Skills that focus on gait and balance engage the cerebellum, interacting with the central nervous system [25]. After a stroke, often seen in the aging population, gait may be affected and the treadmill can help in rehabilitation to improve walking by using different speeds and sensors positioned around the subject to help with this process [26]. After a stroke corticomotor activity can be depressed with regular exercise, which may be a cause for improved outcomes [27]. The hemodynamic status of the brain cortex can also be improved [28]. Along with the post-stroke benefits, it has been hypothesized that there are neuroprotective effects of exercise and fitness. One study observed better preventative capabilities within an animal model with stressful exercise. Male Sprague-Dawley rats were treated to different conditions, including treadmill training, and then a middle cerebral artery stroke was induced. Treadmill training occurred for 30 minutes a day, five days a week, for three weeks. Levels of corticosterone were high in the treadmill group, and this group had a lower infarct volume. The conclusion states that the greater neuroprotection could be from better regulation of heat shock proteins that are stress-induced; the increase in these proteins could potentially allow for greater protection from the inflammatory process post stroke. The authors also stated that a current theory for stroke protection is the change in levels of glutamate that occurs with exercise [29]. Graupe et al. used the functional continuous electric muscle stimulation for paraplegics with the treadmill for therapy in order to help with exercise [30].

Hormones also respond to treadmill training in a beneficial capacity. Growth hormone levels increase during exercise [31]. Also while exercising hormones can be modified to help stabilize hypothyroid disorders [32].

Energy is used more efficiently as the body adapts to treadmill use for exercise. Mitochondrial function and guanine monophosphoryl both increase after training [33,34]. Fatigue can be a problem for cancer patients who have had chemotherapy treatment; workout routines can help the lower extremity kinematics by giving the
user stability and cause less fatigue [35,36]. Endurance is critical to build strength in training, and can be a key factor in healing for people with muscle atrophy, such as in the aging.

One common problem in the aging population is osteoarthritis, which can occur in any joint in the body. This occurs when flexible tissue at the ends of bones wears down, leading to pain and potentially inactivity. Exercise with an appropriate intensity might be recommended for osteoarthritis users and may help reduce inflammation. Using a treadmill, which generally has a softer surface; helps minimize foot impact, thus allowing minimal joint stress [2, 37,38]. Current data on histological analysis shows that there may be changes at a cellular level. One such study supports the hypothesis that lubricin synthesis is increased, which changes the process that breaks down cartilage, thereby showing a positive outcome for osteoarthritis [39].

Neurological physical therapy and cognitive function improvements can result from treadmill training. There have been many medical tests that have been done on the neuro-cognitive benefits of physical and psychological exercise [2,40,41]. A study with Wistar rats concluded that treadmill training may decrease cognitive decline because of the activation of hippocampal ATPase pathways. In the study, rats were divided into two groups, those who just had cognitive training, and those who used treadmills for 20 minutes a day, three days a week, for four weeks [42]. In one study, test subjects ran/walked for a length of time and were tested for memory response after exercise. In most cases the speed in which they answer the questions was faster after the workout than before exercise, possibly due to the cognitive engagement [43]. Another cognitive improvement that can result from treadmill use is the ability to maintain a higher level of social and cultural quality of living [44]. A recent study concluded that the use of treadmills as part of a regular exercise routine improved cognitive activities, such as executive function, memory, and verbal fluency [45].

One neurodegenerative disease is multiple sclerosis, which may also benefit from exercise by decreasing the rate of myelin breakdown [46]. A small randomized control trial concluded that treadmill exercise in patients with multiple sclerosis may increase hippocampal viscoelasticity [47]. After treadmill training, cognitive processing speeds have been proven to improve with the use of treadmill as part of a multiple sclerosis patient's therapy [48].

Parkinson's disease is a disorder the elderly face that causes multiple problems, including tremors, gait disturbances, and cognitive changes. Parkinson's disease symptoms have also demonstrated the benefits of the equipment with exercise. Positive results have been seen in studies; the effects of exercise can reduce the overall symptoms with proper training [49,50]. In a mouse model of Parkinson's disease levels of tyrosine hydroxylase increased, thereby decreasing the destruction of dopaminergic neurons [51]. Similarly, another mouse model observed a decrease in the rate of dopamine turnover, possibly the cause of improved Parkinsonian symptoms. Animals in the study were required to use a treadmill, at a moderate intensity, five times a week, for six weeks [52]. Another rat model concluded that along with improved dopamine levels, exercise caused a decrease in inappropriate neuronal firing [53]. One study determined that with extensive rehabilitation, both in a facility and then at home after discharge, motor and functional independent measure scores were higher than prior to rehabilitation [54]. Studies have shown that dopamine is modulated with exercise and that the ability for glutamate neurotransmission increases along with cerebral blood flow and neurogenesis [55,56]. Another study proposes a combination of aerobic exercise, to increase molecules necessary for synaptic connections, along with exercise with a foundation in skill. They state this combination of therapy may be helpful for neuroplasticity in Parkinson's disease [57].

Dementia is a group of thinking and social symptoms that interfere with daily functioning. Treadmill use can help prevent Dementia later on in life and help with a user's cardiorespiratory level [58]. Alzheimer's disease is a progressive disease that destroys memory, mental functions, and eventually gait. By walking with a regular workout routine, results have shown an impact on slowing neurological diseases, and also help with cognitive functions to slow the progression [59-61]. An animal model of streptozotocin induced neurodegeneration concluded that treadmill exercise increased anti-inflammatory cytokines in the hippocampus, while reducing pro-inflammatory expression, which may improve Alzheimer symptoms. Animals exercised on the treadmill for 30 minutes a day, five days a week, for four weeks [62]. Beneficial cognitive changes in Alzheimer's patients who utilize a treadmill program may be associated with better regulation of ketones and brain glucose levels [63]. One study showed that increased energy output increased neuroprotective agents in the aging population by increasing grey matter [64]. Hippocampal protein MCT1 and 4 levels also increase, providing another neuroprotective aspect [65].

Emotional states may also benefit from regular exercise. The hypothalamic-pituitary-adrenal axis may become more balanced, thereby regulating emotional status [66]. Another positive change is the increase in beta-endorphins, once again allowing for a more positive emotional state and improved pain patterns [67]. Autistic persons are observed to have decreased aggressive outbursts and anxiety-like behaviors with routine exercise [68,69].

A new form of therapy is called virtual reality treadmill training. This training is a computer simulated life that replicates the environment and puts the user into a virtual world of their choice. This training can help a user be able to walk independently and increases the awareness and surroundings to help increase mobility. Studies find that virtual reality can help with extrapyramidal disease users
to achieve independent walking [70]. Training with virtual reality can also help users with Parkinson’s disease in improving balance and obstacle performance when dealing with movement [71].

With any workout a person could have an injury and/or inflammation due to the stress put on the body. One way to counter this inflammation is to treat the site with a device that uses near infrared light emitting diode technology [38]. This device can be used as a coadjutant therapy for after the treadmill. This device also can help with the aches and pains of inflammation and with wound healing.

**Conclusion**

It can be clearly seen that exercise with the treadmill has undergone quite an evolution since its conception. We have shown that the uses of the equipment have gone from labor and punishment to therapy and fitness. During this evolution, numerous changes, modifications, and advancements have been made in order to make this piece of equipment a fixture in today’s modern society. From a medical standpoint, the future of the product use will continue to be helpful in a person’s cognitive rehabilitation, as well as many other physiological improvements. The protective measures of the brain can be correlated to changes of neurotransmitters, hormones, growth factors, and anti-inflammatory agents that can be measured in improvements of cognitive function before and after performance on a treadmill. The aging is a population that can help with the aches and pains of inflammation and with wound healing.

**References**

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