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The Efficacy of Music Therapy as an Alternate Treatment for Parkinson's Disease

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ABSTRACT

Parkinson's Disease (PD) is a neurodegenerative disease characterized by dopaminergic neuron loss, which negatively impacts motor movements and mood (Kalia & Lang, 2015). As a result, dopamine, serotonin, and tropomyosin receptor kinase levels decrease (Politis & Niccolini, 2015). There is no cure for PD (Lew, 2007), but by understanding the effects of music therapy and its mechanisms, we can use music therapy as an adjunctive or alternate treatment for PD.

Introduction

Parkinson's disease (PD) has become more prevalent, as it is now the second most common neurodegenerative disorder, affecting over six million people (Robert et al., 2019). PD is a chronic and progressive disorder in which dopaminergic neurons in the caudate putamen degenerate over time (Vernier et al., 2004). Dopaminergic neurons are essential for motor movements, therefore patients with PD experience diminished motor and non-motor symptoms such as poor motor movement and coordination, tremors, stiffness, balance issues, and negative mood changes. Levodopa is a synthetic dopamine treatment used for over 40 years, which improves PD symptoms in patients and is the preferred initial treatment for PD (Salat & Tolosa, 2013). However, long-term use of levodopa may result in tolerance, fluctuations in motor movements and dyskinesia, psychiatric changes in older patients, and an overall negative impact on the quality of life (Müller & Russ, 2006). In order to combat these side effects, alternative treatments and therapies have been used to alleviate the symptoms of PD and other neurodegenerative diseases. A recent study showed lower levels of depression and delayed levels of cognitive deterioration in elderly patients with dementia who participated in the 12 music therapy sessions when compared to those who did not undergo the 12 sessions of music therapy (Chu et al., 2014). Further exposure to music therapy resulted in a significant increase in the cognitive function ability of those with dementia (Chu et al., 2014), suggesting that music therapies may be a viable option for improving neurodegenerative outcomes. In this review, we will highlight potential mechanisms by which music therapy may affect patients with PD.

Parkinson's Disease

PD is a chronic and progressive disorder in which nerve cells in the caudate putamen, connected by the substantia nigra, degenerate over time (Alexander, 2004); the degenerating nerve cells lose the ability to produce dopamine, rendering the brain incapable of transmitting the necessary signals to initiate and coordinate motor movements (Lindenbach & Bishop, 2013). The cause of PD is unknown, but theories state that genetic factors and environmental toxins could cause PD (Kouli et al., 2018). A recent study suggests that the pesticide rotenone can initiate or accelerate the progression of PD (Pan-Montojo et al., 2012). In mice exposed to rotenone,

there was an increase in alpha-synuclein, which was taken up by presynaptic sympathetic neurites, soon accumulating in the soma (Pan-Montojo et al., 2012). The progression of PD in the mice is based on the accumulation of alpha-synuclein through transneuronal and retrograde axonal transport (Pan-Montojo et al., 2012). Symptoms caused by the degeneration of dopaminergic neurons in the caudate putamen are involuntary tremors and movements caused by muscle stiffness (Truong & Bhidayasiri, 2016). A cognitive impairment produced by PD is dementia, a symptom seen in up to 80% of PD patients (Cosgrove et al., 2015). In a study of 265 PD patients, the three most prevalent complaints of PD symptoms are slowness of motor movement, tremors, and stiffness, respectively, all affecting the quality of life of PD patients (Politis et al., 2010). Music therapy can serve as a treatment for PD, an incurable neurodegenerative disease (*Parkinson's Disease: Challenges, Progress, and Promise*, 2004), through its treatment of the symptoms brought on by PD.

Music Therapy in Parkinson's Disease

Music-specific neural networks are shared amongst the population, allowing for a common appreciation of music. When exposed to musical stimuli such as tempo, pulse, and pitch, the neural oscillations in the brain are rhythmic and repetitive (Zoefel et al., 2018). The brain's capability to encode melodic information suggests that the brain has several mechanisms to interpret musical stimuli. The right side of the brain is known as the musical hemisphere because the comprehension of tempo, pulse, and pitch contour takes place in the superior temporal gyrus and frontal regions, located in the right hemisphere of the brain, implying that not only does the brain inherently comprehend music, but it is also affected by it (Thaut et al., 2014). Music impacts the cerebellum and basal ganglia, affecting motor processing and movements (Grahn & Watson, 2013). In response to musical stimuli, the basal ganglia elicit a stronger activation of the reward processing system, as seen in a recent study in which adult male Wistar rats experienced increased serotonin (5-HT) and dopamine (DA) concentrations in the nucleus accumbens (NAcc) when exposed to musical stimuli (Moraes et al., 2018). 5-HT and DA are both neurotransmitters which can influence mood and motor movements (Fox et al., 2009). Low levels of these neurotransmitters can cause depression, and low levels of 5-HT can impair motor movement (Sasaki-Adams & Kelley, 2001). Music affects the cerebellum by upregulating brain-derived neurotrophic factor (BDNF), a protein that promotes plasticity (Chikahisa et al., 2006). In a recent study, perinatal mice exposed to music had fewer errors in a learning task when compared to mice exposed to white noise. These mice experienced increases in BDNF and TrkBeta in the cerebellum after exposure to music (Chikahisa et al., 2006), suggesting music may have a positive influence on memory, cognition, and neuronal plasticity. Music impacts the prefrontal cortex, eliciting increased levels of BDNF mRNA expression, as seen in Rett syndrome mouse model study (Hung et al., 2021). The Rett syndrome model exposed to music experienced increased levels of BDNF mRNA when compared to mice that were not exposed to music (Hung et al., 2021), suggesting music stimulates plasticity in the prefrontal cortex. Musical stimuli affect serotonin and dopamine levels in the prefrontal cortex, ventral striatum, and amygdala, influencing mood (Moraes et al., 2018). One study demonstrates that rats exposed to musical stimuli experienced increased extracellular dopamine in the basolateral amygdala (BLA), nucleus accumbens (NAcc), and medial prefrontal cortex (mPFC) (Polston et al., 2011), suggesting music therapy is an effective treatment for Parkinson's Disease. A recent study exposed SHR (Spontaneously Hypertensive Rats) to musical stimuli (Sutoo & Akiyama, 2004). When exposed to musical stimuli, increased calcium and brain dopamine synthesis were observed in the exposed SHR (Sutoo & Akiyama, 2004). This study shows that music can increase dopaminergic neuron production. Music therapy is an effective treatment for a variety of neurodegenerative diseases, such as Alzheimer's Disease. Similar to PD patients, AD patients experience increased mood when treated with music therapy (Matziorinis & Koelsch, 2022). Music therapy targets pathways like dopamine synthesis, increasing the production of dopaminergic neurons (Sutoo & Akiyama, 2004). The

increase in dopamine allows for improved mood and motor movements, abilities impaired by PD and other neurodegenerative diseases (Ramesh & Arachchige, 2023).

Music Therapy Efficacy

Music can maintain or increase the degenerating dopaminergic neurons in the caudate putamen of a PD patient (Morris et al., 2019). By enhancing the calcium synthesis process, musical stimuli increase the amount of calcium in the brain (Akiyama & Sutoo, 2011). With increased amounts of calcium ions in the basal ganglia (Monfrini et al., 2023), dopamine synthesis increases (Sutoo & Akiyama, 1997), more effectively producing dopaminergic neurons through the calmodulin-dependent system (Gökçek & Kaydu, 2020). The regular beats in music could lead to increased activity in the putamen, compensating for the lack of dopaminergic stimulation in PD patients (Grahn, 2009). The degenerating dopaminergic neurons in the caudate putamen cause PD patients to struggle to initiate or continue motor movements and experience tremors (Jellinger, 2014). Since dopamine is involved in motor movements (Speranza et al., 2021), increased dopaminergic stimulation could allow for better complex motor movements and coordination. By allowing the rhythm of the music to act as a cue for a motor movement, music can facilitate motor actions through the connection between the patient's auditory perception and movement (Schaefer, 2014). Studies also support that the rhythm of musical stimuli can improve motor movements: gait, speed, frequency, step length, and balance (Ashoori et al., 2015). Music therapy is an effective alternative treatment to levodopa, treating both motor and non-motor symptoms caused by PD. Music therapy can help guide a PD patient's motor movements, allowing for the initiation of motor movements. The rhythm of the music serves as a means for PD patients to make consistent motor movements. Music therapy stimulates the basal ganglia, increasing dopamine levels; due to the increased number of dopaminergic neurons in the brain, the affected motor movements and mood experienced by PD patients improve.

Discussion

Music therapy is an effective, alternate treatment for PD, improving the quality of life of PD patients. However, a prevalent complication of PD affecting the quality of life is the risk of depression in PD patients. Though PD is mainly known for its adverse effects on motor movement and coordination, it can lead to fluctuating mood changes and mood swings. Depression can hasten the deteriorating cognitive and motor functions brought on by PD, complicating any future treatment as the dopaminergic neurons in PD patients become depleted. A PD patient's enjoyment of music and preference of music genre may be influential in treatment with MT (Haslam et al., 2022). MT increases a patient's exposure to music, possibly eliciting hearing symptoms and even leading to permanent hearing damage and loss (Zhao et al., 2010). A study with sixty subjects, ages 15 to 23, demonstrated that exposure to loud music may be harmful, as when exposed to high-resolution sweep-frequency Bekesy tracking audiometry, older subjects exhibited low levels of frequency resolution (West & Evans, 1990). This study suggests exposure to music therapy may cause hearing deficiencies and loss, and deficient levels of frequency resolution are the earliest indicators of hearing damage. However, when practiced correctly, MT can improve hearing in patients and positively influence the auditory perception of the patients (Grenier et al., 2021). Vibrations in music therapy can be effective for hearing-deficient PD patients. A study exposed 40 PD patients to whole-body sound wave vibration (King et al., 2009). After a series of low-frequency sound waves, several symptoms of PD in the patients improved, such as decreased rigidity and tremors in motor movements.

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