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**Original article**

# Tai Chi During and Post-COVID-19 Pandemic: How Much can it Really Benefit Adolescents?

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## Abstract

Adolescents face pressure from their school studies and college admissions, which results in them constantly experiencing symptoms of stress, anxiety, and depression. These symptoms cause sleep quality and concentration to rapidly corrode, which affects their overall mental health. These symptoms have increased in severity as the COVID-19 pandemic progressed, and if left unattended, they will last for a long period, even during post-covid. For the purpose of finding a practical way to combat these effects caused in general, the impacts of practicing Tai Chi on adolescents' general and mental health, as well as the potential underlying mechanisms involved were systematically reviewed through the last 20 years of research. This review provides information on the efficacy of overall health, feasibility, and fundamental knowledge of the practice of Tai Chi. This information could be considered by schools when planning their curriculum and mental health management to support adolescents during and after the pandemic.

**Keywords:** ***Tai Chi, Depression, Stress, Anxiety, Sleep, Concentration, Adolescents, COVID-19***

## 1. Introduction

Today, adolescents face extreme workloads, causing them to be deprived of sleep as they work into the night. Due to COVID-19, adolescents are having even harder times than before due to the health burdens placed on them [1]. Because of school closures, students are faced with a lack of resources that they used to have access to, such as school counselors [2], causing the majority of adolescents to become stressed, depressed, and anxious [1]. Those with Post-Covid [3] may end up with mental health problems, including PTSD, anxiety, and depression (**Figure 1**). Their concentration levels also decrease. Although people may believe that these symptoms are tolerable and temporary, this is usually not the case. If these symptoms are left untreated, there is a small chance of developing long COVID symptoms, which can range from one month to one year [4].

Different methods have been used to release stress, anxiety, and depression. Some of these methods consist of doing light exercises like yoga, or playing sports, like basketball, tennis, soccer, etc. Some people prefer to read books, listen to music, or play video games, while others eat, hang out, or sleep. Some people will even resort to methods such as doing drugs, which could do a lot of harm to them and the people around them [5]. Although some have mental health at their disposal, those who don't may start suffering from the symptoms of stress, depression, and anxiety [4]. Many of these methods are not very effective, and some, such as doing drugs, will worsen the situation [5]. However, there is one exercise, called Tai Chi, that can effectively improve these symptoms (**Figure 2**).

Tai Chi is a martial art that originated in China and is now extremely popular worldwide [6,7]. It is known for its body posture [7], movements, and breathing regulation [6]. It focuses on the mind and the body and sends the mind into a calm state that lets the practitioners relax [7]. It consists of slow movements that require balance, patience, and concentration. Because of this, practitioners will become more mindful and will release negative emotions, such as stress, more effectively [6]. Tai Chi is becoming adopted more as a non-pharmaceutical exercise [8], in places such as college PE courses and in the West. We have created this systematic review to further show the correlation between Tai Chi and its positive effects on adolescents [6].

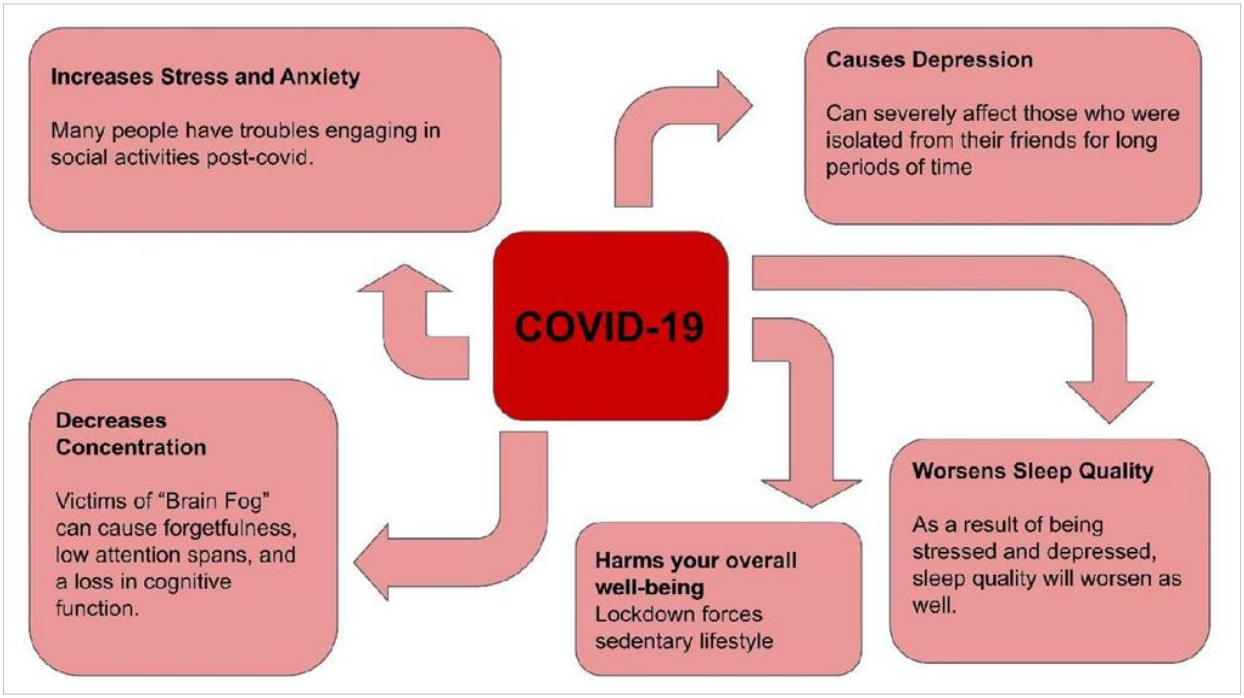


**Figure 1. COVID-19's potential effects on mental health, which will worsen if untreated.**

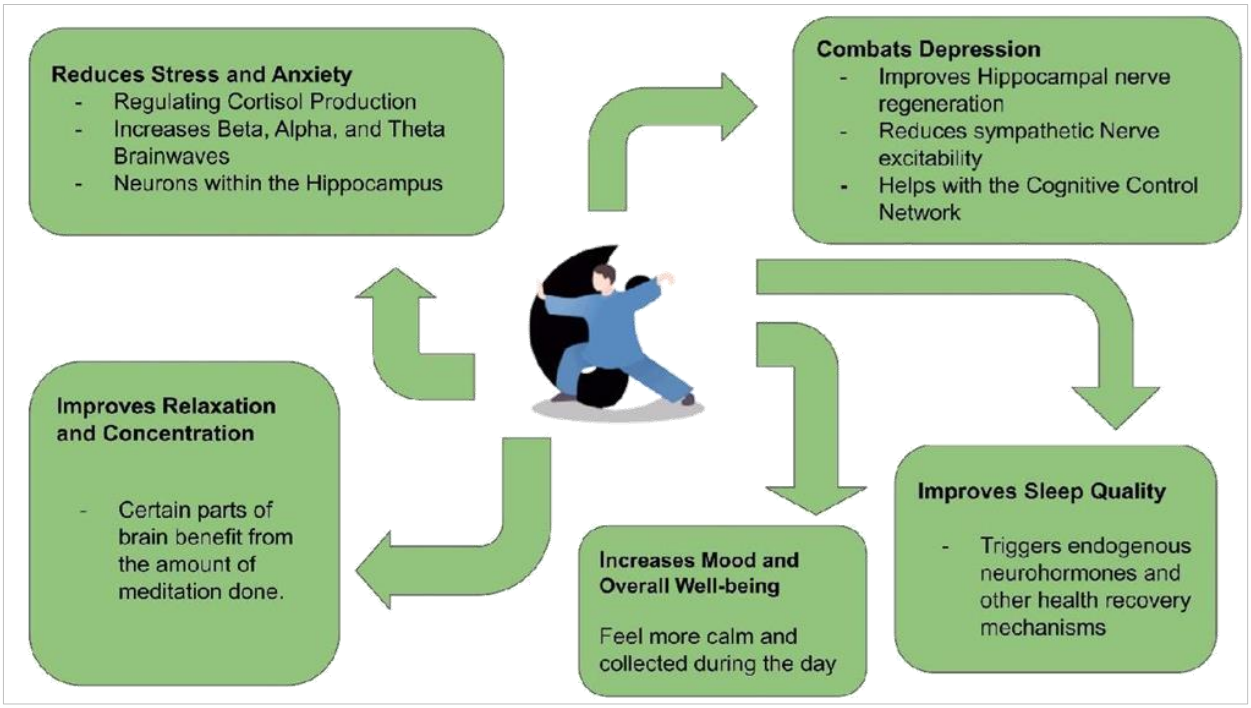


**Figure 2: Tai Chi's potential benefits for mental health. These benefits can help combat COVID-19 symptoms, as well as improve your everyday life.**

## 2. Tai Chi's Anti-Depression Effects through Regulating Parasympathetic Nervous System and Distraction

**Table 1: The benefits of Tai Chi on mental health vs. commonly used methods.**

| | Commonly Used Methods | | Tai Chi | | |
|---|---|---|---|---|---|
| | **Advantage** | **Disadvantage** | **Advantage** | **Disadvantage** | **Underlying Mechanism** |
| **Sleep** | **Drugs:** Improves Sleep quality, gives more energy | Can be very costly and Time-consuming | Improves Sleep quality, gives more energy / No cost at all | None | Practicing Tai-chi can help increase Endogenous neurohormones to be released, which help increase sleep. |
| | **Therapy:** Improves sleep and vitality | Costs money, can be very time-consuming | | | |
| **Anxiety** | **SSRIs, Anxiolytics, Antidepressants:** Decreases Anxiety | Very expensive, and inconvenient | Decreases Anxiety / No cost at all | None | Increases neurons in your hippocampus, which suppresses your anxiety response. |

| | | | | | |
|---|---|---|---|---|---|
| **Depression** | **SSRIs, Antidepressants:** Decreases Depression symptoms | Medication can be extremely expensive | Decreases Depression/No cost at all | | Your attention is shifted from the stressor to Tai-chi movements, thus calming yourself. |
| | **Therapy:** Decreases depression, improves vitality | Costs money, can be very inconvenient and time-consuming | Decreases Stress / No cost at all | None | Increases the effectiveness of Cortisol, which helps regulate your stress response. |
| **Concentration** | **Cognitive Enhancers:** Improves Concentration | Very expensive | Improves Concentration / No cost at all | None | Increases Gray matter in the brain, helping with concentration. |

Tai chi is shown to have effects on mental well-being, thus helping to get rid of depression symptoms. There were 8 studies reviewed on Tai Chi benefiting depression whose results indicate that Tai Chi can have an effect on decreasing depression symptoms [6,9-11]. Out of the 8 studies reviewed, there were 5 studies that held or reviewed randomized controlled trials for adolescents. These trials consisted of a total number of 2223 participants. These participants took 30 to 60-minute classes, over a time span of 8 to 16 weeks [6,10,12-14]. These results showed that the participants had significant improvements in reducing their depressive symptoms.

### 2.1 Hippocampal Nerve Regeneration

A study that held randomized controlled trials has shown that depression is related to the cognitive function of the hippocampal nerve regeneration [9]. Although this has yet to be proven, these studies hypothesize that practicing Tai Chi leads to an improvement in this area. It has also been shown to have an improvement with the remodeling of prominent plasticity, as well as the regeneration of the nerves [9]. By regulating the cognitive function of the hippocampus, Tai Chi can help improve synaptic plasticity, which is important for learning and memory [9]. Synaptic plasticity can also be improved through increasing nerve regeneration, and causing biological changes in one's nerves in order to assist with the practitioner's mood [9].

### 2.2 Negative Emotional Stimuli and Brain Plasticity

Other studies have found practicing Tai Chi to help reduce the time of the functional response under negative emotional stimuli. Due to Tai Chi focusing on the mind and body, Tai Chi practitioners are required to focus on themselves, which helps regulate the central nervous system [9]. Through this, the sympathetic nerve excitability will be reduced, and the autonomic nerve function would be improved [9]. Due to the sympathetic nerve excitability being reduced, this allows the cerebral cortex cells to rest, which would then result in the improvement of the brain's capability to deal with stress, and in turn, also help the brain to deal with depression [9].

One study used a randomized controlled trial in order to determine whether Tai Chi can change brain functional plasticity. Using MRIs, each participant was scanned for 8 minutes before and after the Tai Chi intervention [15]. This study concluded that Tai Chi can indeed change brain functional plasticity. Brain functional network attributes can be split up into two parts: functional segregation and integration. The ability for related groups of brain regions to have specialized processing to occur is what we call functional segregation [15]. An indicator of functional separation is called local efficiency, which reflects information transmission between network nodes. Using the 8-week randomized controlled trial, this study concluded that Tai Chi can help improve local efficiency [15].

#### 2.2.1 Parasympathetic Nervous System

Some studies have suggested that Major Depressive Disorder (MDD) can be associated with decreased activity in the parasympathetic nervous system [11]. When the activity in it decreases, this will cause a decrease in mood that may lead to depression. The heart rate variability component, which monitors the dynamic equilibrium between parasympathetic and sympathetic nervous system activity, has been shown to be inversely correlated with depression extremity. This means that as the parasympathetic nervous system's activity decreases, symptoms of depression will increase [6,11]. However, studies have shown an increase in parasympathetic activity during Tai Chi practice [11].

#### 2.2.2 Cognitive Control Network

Another study hypothesized that Tai Chi can decrease MDD through the cognitive control network, which controls memory and selective attention [11]. When Tai Chi is practiced, the attention is focused on movement and mind, which distracts the mind from the stressor [11]. This study found that Tai Chi can help modify the resting state functional connectivity of the dorsolateral prefrontal cortex, anterior cingulate cortex, and medial prefrontal cortex [11]. The dorsolateral prefrontal is an important area within the cognitive control network, while the anterior cingulate and medial prefrontal cortexes are important areas within the DMN and limbic system [11].

The results of these studies showed that Tai Chi does help improve depression and that it has shown its potential as an exercise to continue to relieve depressive symptoms [6]. However, although many researchers have hypothesized about Tai Chi's underlying mechanism, it is yet to be discovered [11].

## 3. Tai Chi's Anti-stress through Regulating Cortisol Production and Brain Waves

During the COVID-19 pandemic, people were feeling a lot of stress, especially those who were isolated and in online learning. Even today, individuals still feel stressed due to post-covid effects on social and economic factors. Feeling stressed is completely normal and is part of everyone's daily lives, and will not harm you in any way regarding people's cognitive, emotional, and physical functions [16]. However, stress can be good or bad depending on how people respond to the stressor, and one way to respond is through Tai Chi [16]. There were 9 studies examined regarding the benefits of Tai Chi on stress. From the 6 studies that held or reviewed randomized controlled trials, there were a total number of 1757 participants. These participants took Tai Chi classes that ranged from 25 to 90 minutes, over a timespan ranging from 5 weeks to one year. Those who practiced Tai Chi for a longer period of time yielded better results. This encourages consistency in Tai Chi practitioners, as practicing for a longer period of time will yield more benefits. Their overall results indicated that the majority of Tai Chi practitioners had a significant decrease in stress symptoms [16-21].

### 3.1 Cortisol Production

One of the most frequent biomarkers that have been reviewed by many studies is cortisol, and their results show that qigong has a noticeable effect on reducing cortisol levels [17]. When people feel stress, the hypothalamus-pituitary-adrenal axis helps with the production of cortisol hormones and regulates the body's stress response, which reinforces the beneficial effects that Tai Chi has on managing stress levels [7]. Studies that examined the effects of Tai Chi concluded that the exercise significantly reduced cortisol levels compared to the control group [17].

One study that examined Tai Chi's effects on cortisol by testing collected saliva samples from participants with radioimmunoassay [22]. This study found that salivary cortisol levels

decreased significantly during Tai Chi practice. An hour after Tai Chi was performed, the cortisol levels were still approximately the same and did not differ significantly from the levels during Tai Chi practice [22]. In order to ascertain why cortisol levels drop even with a low-intensity exercise, Few [23] found that while the removal rate of plasma cortisol was increased because of the uptake of cortisol by peripheral tissues, the rate of secretion of cortisol was approximately zero.

However, because there is still much to be discovered about the underlying mechanism of Tai Chi's effects, studies regarding biomarkers such as norepinephrine, epinephrine, heart rate, and blood pressure are encouraged to create a more in-depth understanding [17].

### 3.2 Tai Chi's Effects on Brain Waves

Practicing Tai Chi has been proven to increase beta, alpha, and theta brainwaves using EEG recordings. These brain waves are all known to increase meditative state, where beta increases the least, while Theta increases the most [24]. During mindfulness, increased theta waves indicate a parasympathetic state, while alpha and beta waves indicate activity [24]. Brain waves are also shown to have an effect on stress, which can significantly reduce stress symptoms through mindfulness [24].

Another study that measured brain waves recorded EEG using a lycra stretchable cap. They were recorded for 3 minutes before and after the Tai Chi sessions while the participant's eyes were closed [25]. After Tai Chi, the EEG resulted in delta brainwaves being increased by 0.11 and theta brainwaves being increased by 0.54. However, the EEG showed that alpha brainwaves decreased by 0.13, while beta brainwaves didn't change [25]. The benefit of Tai Chi is still shown clearly, as the measurements for theta brainwaves, which increase the meditative state the most, increased by a significant amount [24].

## 4. Tai Chi's Effect on Anti-Anxiety

Tai Chi can help diminish symptoms of anxiety - if not completely relieve it. Adolescents suffer from anxiety, which increases feelings of worry and nervousness wherever they go. There were 5 studies written about Tai Chi and anxiety that we reviewed, and the majority of these studies concluded that Tai Chi does help anxiety. Of the 5 studies reviewed, 4 of them held or reviewed randomized controlled trials. From these trials, there were a total number of 897 participants. These participants took Tai Chi lessons that ranged from 25 to 90 minutes, over a timespan that ranged from 7 weeks to one year [16,17,26,27]. One study, which reviewed the perceived stress and anxiety of college students before and after exams, concluded that although students were able to maintain a moderate level of stress and anxiety, the male students had a relatively moderate percentage of increase of anxiety compared to females [16].

Research from a professor from UC Irvine, Doctor Shin Lin, showed that Tai Chi can help increase neurons in a section of the brain called the hippocampus [28]. In order to obtain this information, Dr. Shin Lin measured the brain waves, heart rates, blood flow, and temperatures of subjects while they were practicing Tai Chi. These neurons help suppress the stress response, as well as anxiety and depression. This is limited to adolescents, adults, and a minority of the older population. Adolescents and adults are burdened with work, while elders may have anxiety disorders. An elder's anxiety may also stem from traumatic experiences from their youth [28].

## 5. Tai Chi's Impact on Sleep

Practicing Tai Chi can help increase the sleep quality of adolescents greatly, allowing them to have better and more refreshing sleep and letting them wake up every day more energized. This mind- body therapy for sleep can also help many adolescents make it through their days easier, and focus more during school. Tai Chi incorporates the mind and body, so practicing it will greatly increase calmness. Other sleep remedies, such as medication, may not work as well as Tai Chi, as medication can cause daytime drowsiness, dizziness, unsteadiness, etc [29]. Tai Chi is also a non-pharmaceutical exercise, which can also benefit those who cannot afford medication [8]. There were 5 studies reviewed on Tai Chi benefiting sleep quality. From the 4 studies that held or reviewed randomized controlled trials, there were a total number of 1419 participants. These participants took lessons that ranged from 1 to 3 hours, over time spans that ranged from 6 to 24 weeks [19,20,29,30]. Many of these studies concluded that Tai Chi can evidently and effectively help decrease sleep disturbances [8,29,30]. This allows adolescents to gain more sleep-in times when they are growing and helps them stay active throughout the day.

### 5.1 Endogenous Neurohormones

The mind and body are always being incorporated when practicing Tai Chi, which gives it a significant advantage over other forms of exercise. It has been hypothesized that by practicing Tai Chi, you focus on your slow movements and body, which can trigger endogenous neurohormones and other health recovery mechanisms to be released [30]. This will help increase states of relaxation and calmness, which results in a night of better sleep. Although the exact mechanisms for Tai Chi benefitting sleep are unknown, studies have also hypothesized that Tai Chi restores the homeostatic balance of the parasympathetic and sympathetic function, by stimulating the parasympathetic nervous system, as well as reducing sympathetic activity [30]. Since insomnia is an extremely common problem for many people, this will be very useful for adolescents and adults, even those who have insomnia, as they all have extreme stress on their shoulders due to schoolwork, homework, activities, and jobs. Better sleep will help them perform better and more efficiently, and will also help prevent health and economic issues [30].

Other researchers found that the average exercise intensity of Tai Chi is 3.1 MET (Metabolic equivalent), meaning that Tai Chi is a low-intensity exercise [29]. These cardiorespiratory responses and energy expenditure were measured using a K4 telemetry system [31]. These researchers believe that the effects of Tai Chi, which includes slow movements and diaphragmatic breathing may lead to a better sense of well-being. They hypothesize that this leads to a better mental state overall, which would help improve sleep quality [29].

### 5.2 Tai Chi's Effect on Insomnia among College Students

One study, which evaluated college students' levels of sleep before and after tests, concluded that the student's sleep time significantly improved during pre-tests and post-tests after practicing Tai Chi [16]. However, one outside factor that may have also led to the improvement in sleep was the fact that the college students were still adjusting to their first semester and slept better as they got used to the environment [16]. Other studies have shown that Tai Chi classes have given a significant impact on the college student's sleep quality, where the participants in these trials were advised to learn and practice mindful Tai Chi exercises in order to prevent insomnia [16].

## 6. Tai Chi Improves Concentration

Taichi can help increase concentration among adolescents. With better concentration, they can perform better when taking classes in high school or in college, which will impact their future positively. There were 5 studies reviewed on Tai Chi benefitting concentration. From the 4 studies that held or reviewed randomized controlled trials, there were a total number of 1867 participants total. These participants took Tai Chi classes that each ranged from 50 minutes to 5 hours (five 1-hour intervals), on a timespan ranging from 5 weeks to one year. Those who practiced Tai Chi for a longer period of time yielded better results, which encourages consistency in Tai Chi practitioners to keep practicing [32-35].

### 6.1 Mindfulness within the Brain

Some studies claim that the anterior cingulate, prefrontal frontal, and posterior cingulate cortices, as well as the insula, striatum, and amygdala, show changes proportional to the amount of mindful meditation done [32]. Tang et al. conducted a review of functional and structural magnetic resonance imaging studies [36]. The anterior cingulate cortex and the striatum are the sections of the brain where the effects of mindfulness training occur. It was also shown that the regulation of emotions is linked to many prefrontal regions, including the striatum and the limbic system [32]. Aside from this, self-awareness and attention are thought to be linked to the posterior cingulate cortex and precuneus [32]. All of this mindfulness training is shown to enhance the density of gray matter within the brain, which enables individuals to have better control over their memory, emotions, and cognitive functions [32]. Another study that investigated the correlation between Tai Chi and Brain Plasticity also concluded that gray-matter volume (GMV) increased in Tai Chi practitioners over a period of 8 weeks, which was measured via MRIs [37]. This will greatly benefit adolescents' studies and improve their concentration at school and home [32].

## 7. Conclusion and Perspectives

Evidence suggests that Tai Chi may be potentially helpful to lessen symptoms of anxiety, depression, and stress, as well as increase sleep quality and concentration. Tai chi is an easy and adaptable exercise that can be practiced non-pharmaceutically [8]. This exercise may not suit everybody, and some may perceive it as very lackluster and boring. However, this is the purpose of Tai Chi - slow movements that encourage mind-body meditation; it is perfectly fine if some do not appreciate this method [7]. A lot more is still to be discovered regarding the underlying mechanisms of Tai Chi's benefits on well-being. Even so, practicing Tai Chi would help many people who do suffer from these symptoms and need more calmness in their lives. Tai Chi should be widely promoted in order to benefit more people's well-being and daily lives. More future studies regarding Tai Chi's mechanisms are warranted.

## Declarations

## Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Author Contributions

EZ and XF conceived the ideas presented in this manuscript. All authors contributed to manuscript preparation.

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