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Effects of Yang-style Tai Chi on body composition and heart rate variability during COVID-19 pandemic among Chinese college students: A preliminary study

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ABSTRACT

Background: COVID-19 restrictions have further reduced college students' opportunities for physical activity (PA), and problems related to physical and physiological health of college students have become increasingly serious. Studying the effect of Tai Chi (TC) on body composition and heart rate variability can provide insights into the potential benefits of TC as a form of exercise.

Objectives: The aim of this study was to assess the effects of 6-week 24-forms Yang-style Tai Chi (YTC) on body composition and heart rate variability (HRV) among college students.

Materials and methods: This single-arm, single-blind, pilot study enrolled 6 beginners from 25 individuals. Body composition and HRV were assessed at the beginning and end of the YTC exercise intervention. The intervention was performed twice a week for 6 weeks, each session lasting 45 minutes and consisting of warming-up, practice, and cooling-down exercises during the COVID-19 pandemic.

Results: After 6-week TC exercise, BMI (21.00±2.61 to 21.20±2.62 kg/m^2) barely changed (p>0.05), while body fat mass, skeletal muscle mass, and basal metabolic rate showed a significant change (p<0.05). In addition, the high frequency (6.68±0.40 to 7.05±0.50 nu) of heart rate variability had a positive significant increase (p<0.05).

Conclusion: The 6-week TC practice had the benefit of improving HRV, such as high-frequency (HF), in college students, but further research is needed to identify the long-term effects of TC on body composition and HRV during the COVID-19 epidemic.

Introduction

Recent years have seen a significant decrease in physical activity (PA) among college students.[1] Prior studies conducted in China found that the highest proportion of exercising time was less than the recommended 1 hour per day at 82.5% and 89.8% in 18-year-old male students and 21-year-old female students, respectively.[2] Improving PA has significant public health implications for preventing many chronic diseases. However, the COVID-19 pandemic has limited people's free access to outdoor areas, such as parks, sports fields, gymnasiums,

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and school-related activities.[3] These isolation strategies further negatively impact the cardio-metabolic health of college students, such as body composition and heart rate variability (HRV).[4] HRV is an important tool in assessing cardiovascular health, representing the variation in the interval between heartbeats that occurs naturally as a result of the interplay between the sympathetic and parasympathetic nervous systems.[5] While the sympathetic nervous system (SNS) is responsible for the "fight or flight" response and increases heart rate, the parasympathetic nervous system (PNS) plays a critical role in maintaining cardiovascular and metabolic health, as well as promoting mental well-being.[6] A lower HRV is generally associated with an increased risk of cardiovascular disease, including aging, obesity, hypertension, and diabetes, higher levels of stress and reduced overall resilience.[7]

A recent systematic review of 33 studies found that PA interventions can have a positive effect on various outcomes, including mental health, physical fitness and quality of life, among college students and other populations during the COVID-19 pandemic.[8] However, most of these studies examined traditional forms of PA, such as aerobic exercise, strength training and yoga, rather than Tai Chi (TC). TC is a unique form of exercise, being low-impact, adaptable and socially connected, that can help enhance PA and mental well-being in college students during the COVID-19 pandemic. Yang-style TC (YTC), the most popular among the Chinese population, focuses on slow, controlled movements and deep breathing, and has been shown to enhance the parasympathetic activity of HRV while improving cardiovascular and metabolic health. In addition, it can also develop mental well-being, specifically the PNS activation that TC training promotes to counteract effects on the SNS, reducing anxiety and improving mood.[9] Compared to a control group, a study found that a 6-week TC intervention significantly improved body composition, such as reductions in body mass index (BMI) and body fat.[10] Another study found that a 24-week, 2-3 times/week, TC intervention significantly improved heart rate variability.[11] Another previous study also showed the high-intensity TC intervention group had greater improvements in body composition than the low-intensity group.[12] Proposed mechanisms for the beneficial effects of TC on body composition and HRV include improved circulation, decreased inflammation and reduced stress.[13] However, it is important to note that the evidence is still limited and further research is needed to confirm the effects of TC on body composition and HRV during the COVID-19 pandemic, as the specific TC program, frequency, duration and intensity of practice may influence the observed effects.

We hypothesized that a 6-week YTC training program could positively affect both body composition and PNS during the COVID-19 pandemic, and we aimed to assess the effect of a defined amount of YTC exercise on body composition and HRV in Chinese college students.

Materials and methods

Participants

Recruited participants were taking the TC course in September 2021 at Huzhou University, China. A total of 25 young people were assessed by questionnaire assessment, of which 19 were excluded due to ineligibility (N=9), refusal to attend (N=6) and dropout (N=4). Inclusion and exclusion criteria follow.

Inclusion criteria: undergraduate students at Huzhou University; age range between 18-24 years BMI ≥18.5 kg/m^2; weight stable as long as 3 months beginning to the study (weight gain or loss less than 4 kg); had enough time and willingness to receive TC training. Exclusion criteria: currently engaging in other weight loss projects; secondary obesity due to medication or other diseases; suffering from hypertension, diabetes, or other cardiovascular diseases; or exercise contraindications; recent withdrawal or medication during the intervention.

Study design

A single-arm, single-blind design was used in this study, and all participants consented to participate in the YTC training program. All participants were familiar with the study tests and procedures prior to baseline measurements. When it came to measuring body composition, subjects needed to step barefoot on the scale, then pull out the handle and touch the eight electrodes on the scale surface and handle respectively and clasp their hands for about 15 seconds. To measure HRV, the end of the subject's index finger needed to be clamped for 2.5 minutes while sitting with eyes closed.

Data were collected at baseline and within half an hour of the end of the 6-week TC training session. All the above group assignment was done by assistants and was hidden from principal researchers.

Intervention

In this study, participants attended supervised Yang-style Tai Chi sessions twice a week for 6 successive weeks. YTC training took place from November to December 2021. It was scheduled to occur every Tuesday and Friday at 4 pm. YTC training is led by an experienced TC-trained instructor. Before the first class, the instructor explained all TC theories and procedures, providing paper materials about its principles and techniques to participants. In subsequent sessions, participants practiced Yang-style TC with an instructor. As YTC is a low-intensity aerobic exercise, popular and easy to learn,[14] every Yang-style TC session lasted approximately 45 minutes, which included a 5-minute warm-up by jogging and stretching, a 35-minute practice, and a 5-minute cooling-down by stretching. During YTC practice, the instructor demonstrated one time on the front and two sides respectively. All participants followed the instructor's motion at the same rhythm 3 times at an interval of more than 1.5 minutes, and then practiced together 5 times in a group. The researcher recorded participant session attendance and the adherence rate was 100%, and all participants' heart rates (HR) mobilized approximately 55% of their maximum HR.

Data collection

Anthropometry and body composition

Anthropometric data were performed by trained and project members according to standardized methods. Height was measured using a portable stadiometer (Height scale, Jiangsu Suhong Medical Equipment Co., Ltd., China), with participants in no shoes and in an upright position. Body composition was measured using an eight-polar tactile-electrode impedance meter (Huawei Smart Scale 3 Pro, Huawei, China), which simultaneously measured BMI, body fat ratio, fat mass, skeletal muscle mass, limb skeletal muscle Index and basal metabolic rate. They were asked to step barefoot on the scale, then pull out the handle and touch the eight electrodes on the scale surface and handle respectively, clasping their hands for about 15 seconds. The height and weight values are accurate to 1 cm and 0.1 kg, respectively. Body mass index (BMI) used a weight/height^2 for calculation.

Heart rate variability

After a 10-minute rest, HRV measurement was made in a sitting position in a quiet and temperature-controlled room (25±1°C). This study used uBioMacpa v70 (BioSense Creative, Korea) to measure stress levels in the autonomic nervous system. The uBioMacpa v70 non-invasively measures the pulse wave of the fingertip capillaries and analyzes the pulse variability of the heart. Using a pulse wave detector identified any abnormalities and measured the body's stress level in the autonomic nervous system. The uBioMacpa v70 measures stress levels according to the mean pulse variation signal analysis guidelines published by the North American Society of Pacing and Electrophysiology and the European Society of Cardiology.[15] Since the measured autonomic nervous system pulse variability could be affected by even small movements, after completing the body composition detection, the pressure level was measured for 2.5 minutes with the hand immobilized on the mat and in a seated position.

HRV main components: high-frequency (HF) means 0.15-0.40 Hz, low-frequency (LF) means 0.04-0.15 Hz, low-frequency/high-frequency ratio (LF/HF), the root means square of successive differences between normal heartbeats (RMSSD) and the standard deviation of NN intervals (SDNN). The HF power is regarded as a marker of cardiac parasympathetic activity.[5] The LF components were mediated by the interaction of sympathetic and parasympathetic nerve activities and could also indicate baroreflex function. LF/HF is a way to quantify the relationship between parasympathetic and sympathetic activity, the sympathovagal balance index.[5] We also followed the standards of the HRV index (unit: ms) measurement and its interpretation. In general, for HF and RMSSD, higher values are considered to indicate higher parasympathetic activity, which is generally beneficial for health, and an increase of the LF and SDNN component is generally considered to be a consequence of increased sympathetic activity. The LF/HF ratio indicates the autonomic nervous system balance.[16]

Statistical analysis

All data were analyzed by SPSS 26.0 (IBM Corp., Armonk, USA) and were checked for normality by the Shapiro-Wilk test. Since BMI, body fat mass, body fat percentage, basal metabolic rate, LF, HF, LF/HF, RMSSD and SDNN were suitable and normally distributed, a paired samples t-test was used to evaluate the differences between before and after 6 weeks of training. Statistical significance was set at $p<0.05$.

Results

Participant characteristics

A total of 6 non-TC experienced participants completed the whole training intervention and were included in this analysis. The mean age of participants was 19.5 years old. Participants did not report any adverse events during the 6-week TC training, including hunger, hypoglycemia, muscle soreness, irritability, or insomnia.

Effect of Tai Chi on BMI and body composition

The present study aimed to investigate the effects of a 6-week TC intervention on participants' body composition and BMI. The findings, as illustrated in Table 1, revealed an increase in body fat mass from 15.63±4.11 kg to 17.77±4.80 kg, and a decrease in skeletal muscle mass from 22.05±2.81 kg to 20.93±2.23 kg. Whereas BMI remained almost unchanged from 21.00±2.61 to 21.20±2.62 kg/m^2.

Table 1 Intervention effects on BMI and body composition.

Variables	Before (mean±SD)	After (mean±SD)	t	*p* value
BMI (kg/m^2)	21.00±2.61	21.20±2.62	-1.54	0.185
BFM (kg)	15.63±4.11	17.77±4.80	-4.12	0.009**
BFR	26.58±4.66	30.07±5.50	-4.78	0.005**
SMM (kg)	22.05±2.81	20.93±2.23	4.04	0.010**
LSMI	6.30±0.66	6.00±0.59	7.89	0.001**
BMR (kJ/m^2·hr)	1283.83±43.75	1248.00±34.63	3.79	0.013*

Note: *BMI: body mass index, BFM: body fat mass, BFR: body fat ratio, SMM: skeletal muscle mass, LSMI: limb skeletal muscle index, BMR: basal metabolic rate, *significant at the 0.05 level (two-tailed), ** significant at the 0.01 level.*

Furthermore, the results indicate that after 6 weeks of TC training, body fat mass and body fat ratio exhibited a statistically significant increase (p<0.01). While skeletal muscle mass, limb skeletal muscle index, and the basal metabolic rate displayed a significant decrease (p<0.05). Notably, despite the observed changes in body composition parameters, BMI remained relatively stable throughout the intervention period (p>0.05), see Figure 1.

Effect of Tai Chi on heart rate variability

The changes in HRV of the participants are shown in Table 2. Although the SDNN increased slightly from 57.18±8.70 to 57.40±13.59 ms, it was found that the LF decreased from 7.78±1.28 to 7.60±0.94 nu. Furthermore, the RMSSD decreased slightly from 53.00±39.31 to 45.46±5.94 ms, but the HF increased significantly from 6.68±0.40 to 7.05±0.50 nu (p<0.05). Moreover, the LF/HF had a decrease from 1.15±0.16 to 1.08±0.14, see Figure 2.

Discussion

We aimed to investigate the effects of 6-week TC training on body composition and HRV among college students. Our results showed that although BMI did not significantly change, other indicators related to body composition, such as body fat and skeletal muscle mass, experienced significant negative changes during the winter COVID-19 epidemic period. While the effect of TC on body composition has been inconsistent in the literature. An exploratory study on the effects of 12 weeks of TC and brisk walking training on weight loss, bone mineral density, and metabolic syndrome parameters in middle-aged adults in Hong Kong provided new information. The study found that both moderate-intensity short-term PA programs slightly reduced body weight and body fat mass and significantly improved waist circumference and fasting blood glucose.[17] Conversely, some TC studies[18-20] have shown no significant changes in body weight or

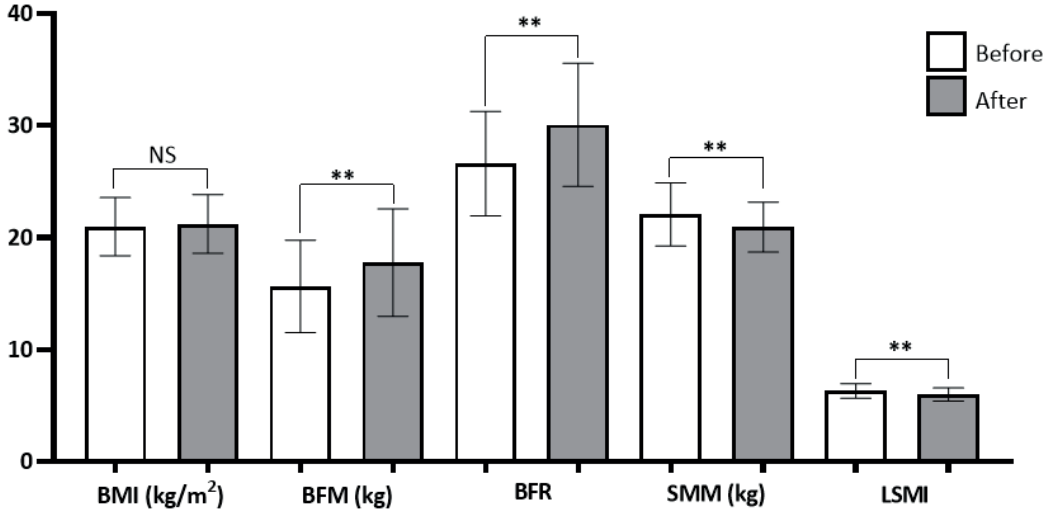

Figure 1 *Changes in body composition before and after the 6-week TC intervention.*
Note: *BMI: body mass index,* BFM*: body fat mass, BFR: body fat ratio, SMM: skeletal muscle mass, LSMI: limb skeletal muscle index, NS: no significant, , *significant at the 0.05 level (two-tailed), ** significant at the 0.01 level.*

Table 2 Intervention effects on heart rate variability.

Variables	Before (mean±SD)	After (mean±SD)	t	*p* value
LF (nu)	7.78±1.28	7.60±0.94	0.676	0.529
HF (nu)	6.68±0.40	7.05±0.50	-3.202	0.024*
LF/HF	1.15±0.16	1.08±0.14	2.000	0.102
SDNN (ms)	57.18±8.70	57.40±13.59	-0.035	0.973
RMSSD (ms)	53.00±39.31	45.46±5.94	0.467	0.66
Composite index	30.83±8.08	31.66±6.02	-0.302	0.758

Note: *LF: low frequency, HF: high frequency, LF/HF: LF to HF ratio, SDNN: SD of NN intervals, RMSSD: root means square of successive differences between normal heartbeats, ms: millisecond, nu: normalized units, which are normalized by subtracting the mean value from each heartbeat interval and then dividing by the standard deviation. It is a dimensionless unit commonly used in the analysis of heart rate variability, * significant at the 0.05 level (two-tailed), ** significant at the 0.01 level.*

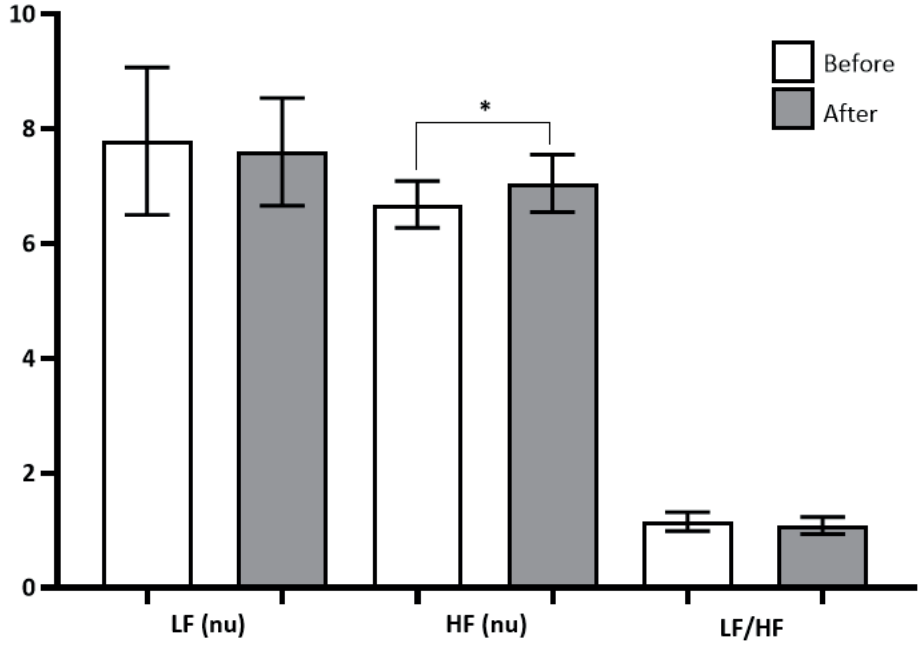

Figure 2 *Changes in LF, HF and LF/HF before and after the 6-week TC intervention.*
Note: *LF: low frequency, HF: high frequency, LF/HF: LF to HF ratio, ms: millisecond, nu: normalized units, which are normalized by subtracting the mean value from each heartbeat interval and then dividing by the standard deviation. It is a dimensionless unit commonly used in the analysis of heart rate variability, * significant at the 0.05 level (two-tailed), ** significant at the 0.01 level.*

BMI. However, we found that 6 weeks of TC exercise slightly increased body fat mass. A possible explanation for this finding is that during the COVID-19 epidemic, the participants may not be able to involved other exercise. This can cause the body fat of college students has increased. This finding is consistent with a previous study, showed a significant rise in weight gain during COVID-19 among individuals who had a 6-week long winter vacation in the USA and UK.[21] However, it is important to note that the heterogeneous findings suggest that study designs, target population, frequency, season, and duration of TC exercise are all important factors in detecting significant clinically relevant effects. [22-24]

It is important to consider the impact of various factors on the results of this study, such as a small sample size, short duration of intervention, and differences in the participants' baseline characteristics. Due to the nature of skeletal muscle mass and basal metabolic rate adaptations, it is unlikely that significant changes would be immediately apparent after only six weeks of exercise training. Longer periods of consistent training are typically required to observe such adaptations. Although efforts were made to recruit participants with similar baseline levels, it is possible that some individuals may have had poor body composition or mental health initially. This would result in more significant improvements post-intervention compared to those with relatively good body composition at baseline. Additionally, it is important to note that some factors not considered in this study, such as exercise dosage and food intake, may have influenced changes in body composition. However, it is interesting to note that HRV indicators showed positive improvement within six weeks of TC intervention. There was consistent with the H. ChuDuc,'s study which found improvements in the HF component and a decrease in the LF.[25] This study also observed a decrease in the LF/HF after the TC intervention, but it was not statistically significant. This finding is partially consistent with the results of some studies that have observed a significant decrease in LF/HF. [26,27] It is crucial to note that HRV parameters, including HF, LF, RMSSD, and SDNN, are complex and dynamic measures that depend on individual physiological and environmental factors.

Since TC is a light-to-moderate intensity aerobic exercise that combines physical and mental exercises, it is widely believed that TC involves the control of physical tension and mental concentration, which may promote stress relief by reducing sympathetic drive and increasing parasympathetic drive, as reflected in HRV.[28] The mechanism of how slow, rhythmic breathing and focused TC training affects HRV is not fully understood, but it is thought to be related to improvements in autonomic nervous system (ANS) function and stress regulation.[29] TC may stimulate the parasympathetic branch of the ANS, reduce sympathetic activity, and enhance HRV by improving baroreflex sensitivity (BRS), reducing inflammation and oxidative stress, and improving psychological well-being. Moreover, TC has been shown to enhance parasympathetic activity, improve cardiovascular and metabolic health, and promote mental well-being.[30] Specifically, parasympathetic activity reduces heart rate and blood pressure to protect against cardiovascular disease, improves blood sugar regulation, enhances digestion and nutrient absorption, and promotes fat metabolism. TC

training activates the parasympathetic nervous system, indicating an HF increase, which counteracts the effects of the sympathetic nervous system,[31] and parasympathetic activation can reduce anxiety and improve mood by promoting relaxation and reducing stress hormones like cortisol.[30] Therefore, 6 weeks of TC training may lead to improvements in both HF and LF of HRV, indicating a shift towards a more balanced and flexible autonomic nervous system. This is consistent with previous research that has shown that TC can enhance parasympathetic activity and improve cardiovascular function, which may in turn improve HRV.

It is certainly worth noting that the COVID-19 situation has had a multifaceted impact on TC training, body composition, and HRV. [4] For example, individuals may have to adapt their training and lifestyle habits in response to challenges posed by COVID-19, such as reduced interaction opportunities during TC training due to social distancing. They can also change in dietary habits, sedentary behavior, and increased stress. Future studies with sufficient interventional duration may lead to more significant results. However, this study provides a valuable strategy for improving HRV, especially the HF of parasympathetic activity, during the winter of the COVID-19 epidemic through a 6-week TC exercise intervention. It is important to note that only 10% of the Chinese population has a good health conception and culture. Additionally, many students report spending less than one hour per day on PA which highlights the need for interventions like TC to promote physical and mental health.[2] The results of this study show that TC can not only serve as a means of promoting sports culture but can also significantly increase the HF component of HRV, indicating increased parasympathetic activity and decreased sympathetic activity.

This study presents preliminary evidence on the effects of Yang-style Tai Chi sessions twice a week for 6 weeks consecutively may promote in the parasympathetic activity of college students in the epidemic, as increases in HF. However, it should be noted with caution that the results of previous studies on the effects of TC on HRV and body composition have been inconsistent. Further research is needed to draw more reliable conclusions. This study has some limitations, including small sample size and the lack of a control group due to it being a preliminary study. We were mainly to verify whether 6 weeks of TC has an impact on body composition and HRV and to verify the operability of the protocol. Moreover, our study did not measure psychological stress directly. It is also better if future research should incorporate psychological questionnaires to provide a more comprehensive assessment of the effects of TC on stress. A well-designed study with a larger sample size and a control group is currently underway to address these limitations.

Conclusions

This study highlights the potential benefits of TC for improving HRV, especially during challenging times like the COVID-19 epidemic. However, further research is needed to establish the long-term effects of TC on body composition, stress, and HRV, and to identify the functions for promoting physical and mental health among college students.

Conflicts of interest

The authors declare no conflict of interest.

Ethical approval

The experimental protocol was approved by the Center for Ethics in Human Research, Khon Kaen University, and Recorded No.4.2.01: 6/2565 (Reference No. HE652012). All participants signed written informed consent in the study.

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