A COMPARATIVE STUDY ON ENERGY EXPENDITURE AND HEART RATE RESPONSE OF OVERWEIGHT BEGINNERS IN TWO DIFFERENT TAI CHI STYLES

Yantao Niu[1,2], Rojapon Buranarugsa[1,3] and Piyathida Kuhirunyaratn[4]

[1]Exercise and Sport Sciences Program, Graduate School, Khon Kaen University

[2]Faculty of Physical Education, Jiaozuo Normal College, Jiaozuo, China

[3]Physical Education Program, Faculty of Education, Khon Kaen University

[4]Department of Community Medicine, Faculty of Medicine, Khon Kaen University

Abstract

This study aimed to compare the energy expenditure and exercise intensity of Bafa Wubu Tai Chi (BW-TC) and Traditional He-style Tai Chi (TH-TC) groups during 30 minutes of practice. Twenty eligible participants, aged 18-23 years, with a BMI ranging from 24 to 27.9 kg/m^2, were divided into BW-TC (n=10) and TH-TC (n=10) groups. Baseline characteristics were measured using a height-weight scale. After two weeks of Tai Chi training, demonstrate the required movements under the guidance of the instructor, then Energy expenditure and exercise intensity were assessed during a 30-minute Tai Chi training session using a heart rate monitor. The measurement tool was the Polar H10 Heart Rate Monitor. Descriptive statistical methods summarized the baseline characteristics of the participants, and an independent samples t-test was used to compare baseline differences between the two Tai Chi groups and assess parameters during the 30-minute Tai Chi practice. Results showed the TH-TC group exhibited significantly higher values than the BW-TC group in maximum heart rate (141.80 ± 10.83 bpm > 117.50 ± 10.97 bpm), average heart rate (115.30 ± 7.21 bpm > 98.80 ± 10.77 bpm), heart rate after 30 minutes of exercise (119.30 ± 13.71 bpm > 100.70 ± 10.54 bpm), energy expenditure (222.30 ± 22.84 Kcal > 184.10 ± 13.41 Kcal), and exercise intensity (5.75 ± 0.66 METs > 4.65 ± 0.40 METs) (p<0.001). Conclusions found that TH-TC resulted in higher energy expenditure and exercise intensity compared to BW-TC. Incorporating TH-TC into exercise programs may offer individuals an effective means to enhance cardiovascular fitness and calorie burning.

Keywords: Bafa Wubu Tai Chi, Traditional He-style Tai Chi, Energy expenditure, Exercise intensity, Overweight beginners

Corresponding Author: Asst.Prof.Rojapon Buranarugsa, Ph,D., Physical Rducation Program, Faculty of Education, Khon Kaen University. Email: rojapon@hotmail.com

Introduction

Recent research findings indicate that 22.7% of Chinese students aged 19-22 are grappling with the issue of overweight or obesity, with 8.4% of female students affected (Chen et al., 2020). The prevalence of this condition poses a significant public health concern, as it adversely impacts various physiological functions and places a substantial burden on individuals and society as a whole (Ten Hoor, Kok, Peters, Frissen, Schols, & Plasqui, 2017). Scientific investigations have highlighted the correlation between a high incidence of overweight or obesity, sedentary lifestyles, and an elevated risk of chronic ailments such as coronary heart disease (Garber et al., 2011); cardiovascular disease (Czernichow, Kengne, Stamatakis, Hamer, & Batty, 2011); musculoskeletal disorders (Anandacoomarasamy, Caterson, Sambrook, Fransen, & March, 2008); depression (Blüher, 2019); and premature mortality (Leinaar, Alamian, & Wang, 2016). These detrimental consequences greatly compromise the overall quality of life, work productivity, and escalate healthcare expenses.

Engaging in regular physical exercise presents a promising avenue for mitigating the risk factors associated with overweight or obesity - related conditions. It encompasses weight reduction, enhanced muscle mass, improved body composition, increased physical strength and fitness levels, optimized blood lipid profiles and cardiopulmonary indicators, decreased body fat percentage, and enhanced flexibility, muscle strength, endurance, and cardiorespiratory fitness (Liu et al., 2019). Previous investigations have unveiled a diverse range of exercise modalities that can effectively curtail or manage the potential adverse factors associated with overweight or obesity, thus underscoring the positive impact of exercise in mitigating the potential harm faced by this population segment.

Tai Chi, an ancient Chinese practice rooted in the principles of Chinese medicine and martial arts, encompasses both physical and mental exercises (Cetin, Erel, & Bas Aslan, 2020). Evidence from previous research suggests benefits of Tai Chi practice in terms of improved respiratory function (Patel, Tu, & Gittner, 2023); cardiovascular (Lin, Jin, Liu, Zhao, & Ji, 2022); metabolism (Leung, Chan, Sit, Liu, & Taylor - Piliae, 2019); nerve (Zhang et al., 2023); physical fitness (Nyman et al., 2019). By integrating fluid movements, synchronized breathing, and minded awareness, Tai Chi seeks to cultivate a harmonious connection between the mind and body (Lee, Lee, & Woo, 2007). Scientific research has highlighted the potential of Tai Chi in improving various risk factors associated with overweight or obesity, including physical fitness and biomarkers, thereby substantiating its health - promoting effects (Shou et al., 2019). However, there remains a dearth of comparative intervention studies specifically examining the impact of traditional and modified Tai Chi practices on overweight college students. Existing research has predominantly focused on adolescents, middle - aged, and elderly populations, further underscoring the need for investigations targeting this particular demographic.

A comparative study investigating the physiological characteristics of a newly developed Simplified Bafa Wubu Tai Chi (BW-TC) and the traditional He-style Tai Chi (TH-TC) in overweight or obese individuals has filled a research gap and highlighted areas for future exploration. BW-TC is a simplified Tai Chi routine promoted by the Chinese National Sports Administration.

It consists of 16 basic forms that can be completed in approximately 3 minutes, and is suitable for different types of practitioners (Lyu et al., 2020). It focuses on simple and fundamental movements and techniques, emphasizing the softness and coordination of the body. In contrast, TH-TC is a traditional form of Tai Chi that comprises 72 forms with more complex movements. Each form takes around 5 - 8 minutes to complete and emphasizes the integration of internal and external elements, the combination of movement and stillness, and the regulation of intention. The exercise intensity is appropriate and safe for overweight beginners. A previous intervention similar to Tai Chi did not cause injuries to obese people and improved cardiovascular disease risk factors (Sun et al., 2019). It emphasizes the cultivation of internal energy and the application of energy in the body. To date, the differences in exercise intensity and energy expenditure between the newly developed BW - TC and the TH - TC have not been investigated. Therefore, this study aimed to primarily compare the differences in exercise intensity and energy expenditure between these two distinct Tai Chi styles. We hypothesized that the newly developed BW-TC may have lower exercise intensity and energy expenditure compared to the TH - TC.

Research Question

Which one is higher in energy expenditure and exercise intensity between the two types of Tai Chi in a 30 - minute practice?

Hypothesis

TH - TC may have higher energy expenditure and exercise intensity compared to BW - TC in a 30 - minute Tai Chi practice.

Purpose of this study

This study aimed to compare the energy expenditure and exercise intensity of BW-TC and TH-TC groups during 30 minutes of practice.

Materials and methods

Study design

This study protocol was approved by the Khon Kaen University Ethical Committee for Human Research (approval no. HE642132). In this randomized controlled study, participants underwent baseline measurements, including height, weight, age, and BMI, to assess their basic characteristics. Subsequently, participants were randomly assigned to either the BW-TC group (n=10) or the TH-TC group (n=10) to participate in a two - week Tai Chi training program. They were able to demonstrate the required movements under the guidance of the instructor, the exercise intensity and energy expenditure were dynamically measured using a Polar (H10) chest strap. The study was conducted from September 27, 2021, to October 11, 2021, with duration of two weeks. Figure 1 outlines the entire intervention process and the effects of progress in this pilot study according to the Consolidated Standards for Reporting Trials (CONSORT) criteria.

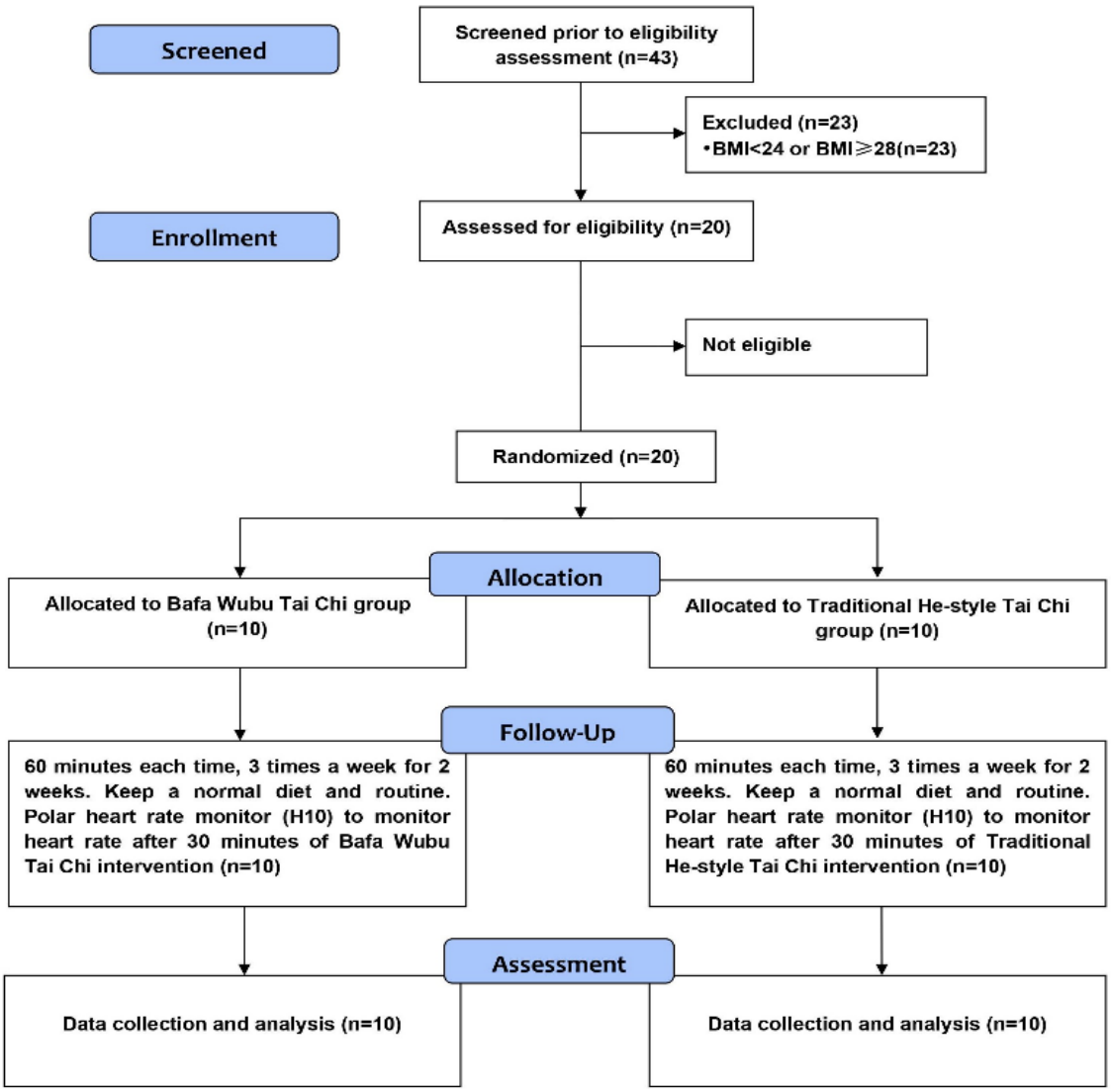


Fig 1. Flowchart of the Consolidated Test Reporting Standard (CONSORT) experimental process

Participants

In this study, a total of 43 overweight male college students were recruited from Jiaozuo Teachers College in China. Among them, 20 eligible participants were randomly assigned to either the BW - TC group (n=10) or the TH - TC group (n=10). The inclusion criteria for participants were males between the ages of 18 - 23, enrolled as freshmen or sophomores, and with a BMI ranging from 24 to 27.9. Exclusion criteria included individuals who regularly practiced Tai Chi, were members of any sports association, or had severe cardiovascular or musculoskeletal disorders.

Research Tools

In this study, the H10 heart rate monitor (Heart Rate Monitor) from Polar was employed to monitor the heart rate and energy expenditure of each participant after 30 minutes of Tai Chi intervention.

Tai Chi training program

The trial involved two distinct groups: the BW - TC group, which followed a simplified Bafa Wubu Tai Chi regimen (Lyu et al., 2020), and the TH - TC group, which practiced traditional He - style Tai Chi. Both groups participated in a 2 - week intervention, attending 3 sessions per week. These sessions were held after regular class hours, specifically on Mondays, Wednesdays, and Fridays from 5:30 pm to 6:30 pm, and were led by qualified Tai Chi instructors. Each intervention session included a 15 - minute warm-up, followed by a 30 - minute Tai Chi practice session, and concluded with a 15 - minute cool-down period. Throughout the training process, the BW - TC group received detailed descriptions and explanations of 16 movements, covering the sequence of movements, body postures, and transitions between movements. The emphasis was on changes in body weight distribution, natural breathing, and the coordination of intention with movement. It was explicitly mentioned that completing all movements typically took about 3 to 5 minutes. For the TH - TC group, detailed descriptions and explanations of 72 movements were provided, including the execution sequence, body postures, transitions between movements, and the range of body movements and weight distribution fluctuations. The emphasis was on integrating internal and external aspects of movements and combining body posture with mental cultivation. It was also noted that completing all movements typically took about 5 to 8 minutes. These differences highlighted the distinctive practice styles of the two Tai Chi forms. At the end of the training, Tai Chi experts assessed the participants' proficiency in both Tai Chi styles through evaluation tests. If participants were not sufficiently skilled, instructors provided further guidance for practice. To ensure research quality, the main researchers, Tai Chi instructors, and evaluators were independent individuals, separate from one another.

Intensity energy consumption test

Baseline measurements were taken using the Bingyu RGZ-160 height-weight scale to measure height and weight. Body Mass Index (BMI) was calculated using the formula weight / height2 (Lohman, Roache, & Martorell, 1992). After two weeks of Tai Chi training, participants' proficiency in practicing the different Tai Chi styles and movements was assessed. They were able to demonstrate the required movements under the guidance of the instructor. Subsequently, we conducted an evaluation of their heart rate and energy expenditure during a 30 - minute practice session. For the measurement of heart rate and energy expenditure during 30 minutes of Tai Chi training, we utilized the Polar H10 heart rate monitor, which has been proven reliable in assessing heart rate in previous studies (Speer, Semple, Naumovski, & McKune, 2020). Prior to the tests, appropriate calibration and adjustments were performed, including checking the battery level, ensuring correct sensor and device connections, and verifying the proper functioning of the equipment to ensure accurate recording of heart rate data. Additionally, participants were instructed to adhere to specific dietary control requirements to minimize potential dietary effects on heart rate. Following the guidelines provided by the heart rate monitor, it was worn on the chest, in close contact with the skin, to record maximum heart rate, average heart rate, and energy expenditure after the 30 - minute Tai Chi intervention. The MET

(Metabolic Equivalent) value was calculated using the formula METs = (energy expenditure / (body weight (kg) x duration of exercise (hours))) / 3.5, where METs represent the metabolic cost of the activity relative to resting metabolic rate. Each participant's MET value was calculated, and the maximum heart rate was used to assess exercise intensity. The value 3.5 represents the resting metabolic rate and serves as the basis for defining 1 MET as the resting metabolic rate (Chin et al., 2022).

Statistical analysis

Data analysis was performed using SPSS 26.0 software (IBM Corp., Armonk, USA). All data were presented as mean ± standard deviation. Prior to further analysis, the Shapiro-Wilk test was conducted to assess the consistency and normal distribution of the collected data. Descriptive statistics were used to summarize the baseline characteristics of the participants, including height, weight, age, and BMI. To compare the differences in exercise intensity and energy expenditure during the 30-minute training between the BW-TC group and the TH - TC group, an Independent Samples t - test was employed. A significance level of $p < 0.05$ was considered statistically significant, while $p < 0.01$ was considered highly significant.

Results

The study recruited a total of 20 overweight male college student participants, with a mean age of 18.35 ± 0.50 years, a mean height of 173.9 ± 4.33 cm, a mean weight of 78.90 ± 4.97 kg, and a mean BMI of 26.05 ± 1.39 kg/m^2. Table 1 summarizes the baseline demographic data of the study groups, including age, weight, height, BMI, and comparison between two groups at baseline.

Table 1. Comparison of groups in terms of demographic data at baseline

Parameters	Mean ± S.D.		*p-value*
	BW-TCG (*n*=10)	TH-TCG (*n*=10)	
Age (years)	18.30 ± 0.48	18.40 ± 0.52	0.660
Height (cm)	173.50 ± 3.87	174.30 ± 4.79	0.686
Weight (kg)	79.40 ± 5.09	77.70 ± 3.20	0.384
BMI (kg/m^2)	26.36 ± 1.22	25.61 ± 1.31	0.202

Note: Independent t-test was used for all other group comparisons. BMI = body mass index; BW-TCG = Bafa Wubu Tai Chi group; TH-TCG = Traditional He-style Tai Chi group; S.D. = standard deviation; cm. = centimeter; kg. = kilogram.

Table 2 shows the data of statistics that Polar H10 measured the max heart rate (HR), min HR, average HR, HR of after 30 minutes of exercise, energy expenditure (Kcal) and exercise intensity (METs). TH-TC group compared with BW-TC group in max HR (141.80 ± 10.83 bpm > 117.50 ± 10.97 bpm), average HR (115.30 ± 7.21 bpm > 98.80 ± 10.77 bpm), HR after 30 minutes of exercise (119.30 ± 13.71 bpm > 100.70 ± 10.54 bpm), energy expenditure (222.30 ± 22.84 Kcal > 184.10 ± 13.41 Kcal) and exercise intensity (5.75 ± 0.66 METs > 4.65 ± 0.40 METs), the equal means were greater than the BW-TC group for all parameters, with a statistically significant

difference (p<0.001). To make the results clearer, Figure 2 shows the comparison of the test variables of these two different types of Tai Chi after 30 minutes of practice.

Table 2. Maximum HR, Minimal HR, Average HR, End of HR, Calories and Exercise Intensity in 30 min during BW-TC and TH-TC

Parameters	Mean ± S.D.		*t*	*p-value*
	BW-TCG (n=10)	TH-TCG (n=10)		
Maximum HR (bpm)	117.50 ± 10.97	141.80 ± 10.83	-4.99	0.000***
Average HR (bpm)	98.80 ± 10.77	115.30 ± 7.21	-4.03	0.001**
30-HR (bpm)	100.70 ± 10.54	119.30 ± 13.71	-3.40	0.003**
Energy expenditure (kcal)	184.10 ± 13.41	222.30 ± 22.84	-4.56	0.000***
Exercise Intensity (METs)	4.65 ± 0.40	5.75 ± 0.66	-4.50	0.000***

Note: Independent t-test, ** p < 0.01; *** p < 0.001. BW-TCG = Bafa Wubu Tai Chi group; bpm = Beat per minute; TH-TCG = Traditional He-style Tai Chi group; HR = heart rate; 30-HR = Heart rate after 30 minutes of practice; SD = standard deviation.

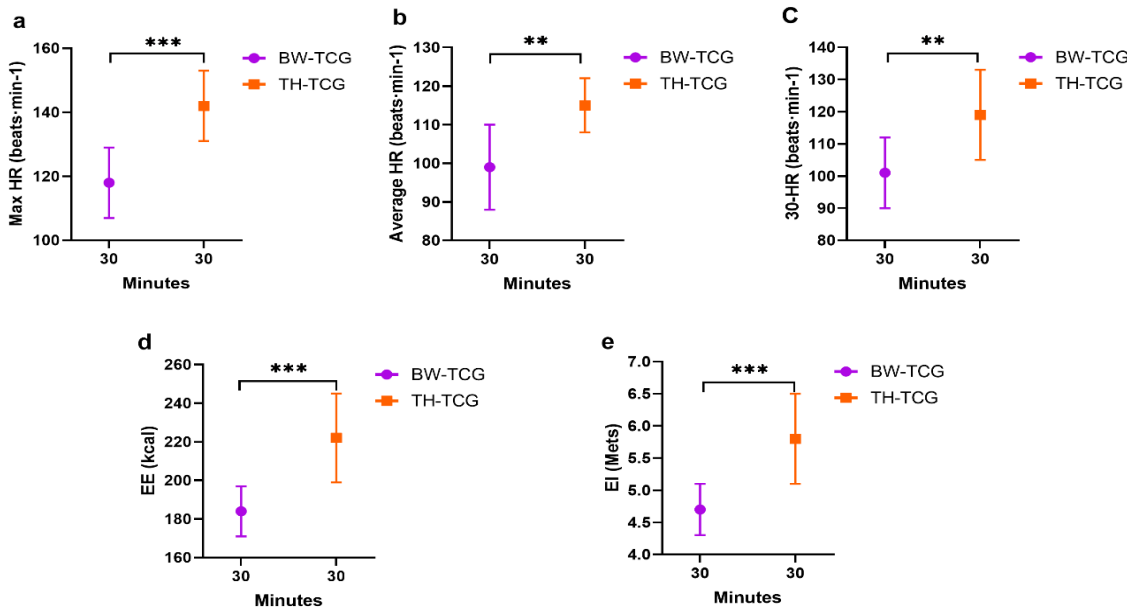


Figure 2. Comparison results of two different types of Tai Chi in terms of energy expenditure and exercise intensity test variables. Abbreviations: BW-TCG, Bafa Wubu Tai Chi group; TH-TCG, Traditional He-style Tai Chi group; Max HR, maximum heart rate; Average HR, average heart rate; 30-HR, Heart rate after 30 minutes of practice; EE, Energy expenditure; EI, Exercise Intensity; Mets, metabolic equivalents. ** represents p<0.01, *** represents p<0.001.

Discussion

The present study aimed to compare the effects of Bafa Wubu Tai Chi group (BW - TCG) and Traditional He - style Tai Chi group (TH - TCG) on energy expenditure and exercise intensity. The results revealed that the TH-TC group exhibited significantly higher values than the BW - TC group in terms of maximum heart rate, average heart rate, and heart rate after 30 minutes of exercise, energy expenditure, and exercise intensity.

The findings of this study have important implications for individuals seeking to engage in Tai Chi as a form of exercise. The significantly higher maximum heart rate observed in the TH - TC group (141.80 ± 10.83 bpm) compared to the BW-TC group (117.50 ± 10.97 bpm) suggests that TH - TC imposes a greater cardiovascular load and provides a more intense cardiovascular workout. This finding indicates that individuals practicing TH - TC can achieve a higher level of cardiovascular fitness compared to those practicing BW - TC.

In addition, the TH - TC group demonstrated significantly higher average heart rate and heart rate after 30 minutes of exercise, further supporting the higher intensity of TH - TC. These results suggest that the TH - TC style of Tai Chi elicits a sustained increase in heart rate throughout the exercise session, promoting cardiovascular endurance and aerobic fitness.

Furthermore, the TH - TC group exhibited significantly higher energy expenditure (222.30 ± 22.84 kcal) and exercise intensity (5.75 ± 0.66 METs) compared to the BW - TC group (energy expenditure: 184.10 ± 13.41 kcal, exercise intensity: 4.65 ± 0.40 METs). This implies that TH - TC leads to greater calorie burning and elevated metabolic rate, which may have positive implications for weight management and cardiovascular health. Individuals aiming for weight loss or improved metabolic health may find TH - TC more effective in achieving their goals.

The observed differences in energy expenditure and exercise intensity between the two Tai Chi styles can be attributed to the distinct advantages of TH - TC over BW - TC in terms of movement complexity, lower limb muscle activity, and integration of internal and external elements. Firstly, TH - TC involves more complex and longer duration movements, requiring participants to engage in a greater range of lower limb movements and muscle contractions (Hao, Hong & Youlu, 2007). In contrast, BW - TC features simplified movements with less involvement of lower limb muscles (Li et al., 2023). Secondly, TH - TC emphasizes the integration of internal and external elements, the combination of movement and stillness, and the regulation of intention. This focus on internal energy and energy utilization results in more powerful, fluid, and rhythmic movements, as well as increasing exercise intensity. These factors collectively support the notion that TH - TC, compared to BW - TC, leads to higher exercise intensity and energy expenditure during Tai Chi practice. Although research specifically investigating the exercise intensity of TH - TC is lacking, we can draw parallels to classical Yang Style Tai Chi, which is considered a medium - intensity exercise (Lan, Chen, & Lai, 2008). The similarity in practice methods, ranges, and completion times between TH - TC and classical Yang Style Tai Chi supports the classification of TH - TC as a more intensive form of Tai Chi practice.

It is important to acknowledge the limitations of the present study. First, the sample size was small, which may limit the generalizability of the findings to a larger population. Future studies with larger sample sizes are warranted to validate these findings. Additionally, the study employed a short - duration, single - session protocol, which may not fully capture the long - term effects of different Tai Chi styles on energy expenditure and exercise intensity. Long - term observations and training interventions would provide a more comprehensive understanding of the benefits associated with each style.

Conclusions

Our study found that Traditional He-style Tai Chi (TH - TC) results in higher energy expenditure and exercise intensity compared to Bafa Wubu Tai Chi (BW - TC). Traditional He-style Tai Chi elicits a more vigorous workout and has the potential to provide greater cardiovascular benefits. However, further research with larger sample sizes and diverse populations is warranted to validate these findings and explore the long-term effects of different Tai Chi styles on energy expenditure and exercise intensity.

Acknowledgments

This work was supported by the 2022 Key University Research Project of the Department of Education of Henan Province (no. 22B890001). The authors would like to acknowledge the support of all the participants, and the technical experts from Jiaozuo Tai Chi Sports Centre for providing testing equipment services.

References

Anandacoomarasamy, A., Caterson, I., Sambrook, P., Fransen, M., & March, L. (2008). The impact of obesity on the musculoskeletal system. *International Journal of Obesity*, *32*(2), 211–222. https://doi.org/10.1038/sj.ijo.0803715

Blüher, M. (2019). Obesity: global epidemiology and pathogenesis. *Nature Reviews Endocrinology*, *15*(5), 288–298. https://doi.org/10.1038/s41574-019-0176-8

Cetin, S. Y., Erel, S., & Bas Aslan, U. (2020). The effect of Tai Chi on balance and functional mobility in children with congenital sensorineural hearing loss. *Disability and Rehabilitation*, *42*(12), 1736 - 1743. https://doi.org/10.1080/09638288.2018.1535629

Chen, Y., Liu, X., Yan, N., Jia, W., Fan, Y., Yan, H., ... Ma, L. (2020). Higher academic stress was associated with increased risk of overweight and obesity among college students in China. *International Journal of Environmental Research and Public Health*, *17*(15), 1 - 12. https://doi.org/10.3390/ijerph17155559

Chin, E. C., Leung, C. K., Yu, D. J., Yu, A. P., Bernal, J. K., Lai, C. W., ... Siu, P. M. (2022). Effects of one-year once-weekly high-intensity interval training on body adiposity and liver fat in adults with central obesity: Study protocol for a randomized controlled trial. *Journal of Exercise Science & Fitness*, *20*(2), 161 - 171. https://doi.org/10.1016/J.JESF.2022.03.003

Czernichow, S., Kengne, A. P., Stamatakis, E., Hamer, M., & Batty, G. D. (2011). Body mass index, waist circumference and waist-hip ratio: Which is the better discriminator of cardiovascular disease mortality risk? Evidence from an individual-participant meta-analysis of 82864 participants from nine cohort studies. *Obesity Reviews*, *12*(9), 680 - 687. https://doi.org/10.1111/j.1467-789X.2011.00879.x

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., ... Swain, D. P. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Medicine and Science in Sports and Exercise*, *43*(7), 1334 - 1359. https://doi.org/10.1249/MSS.0b013e318213fefb

Hong, H & Youlu, H. (2007). Commentary on He-style Taijiquan. *Henan Social Sciences (China)*, *15*(5), 9 - 12.

Lan, C., Chen, S.-Y., & Lai, J.-S. (2008). *The Exercise Intensity of Tai Chi Chuan*. Retrieved from https://doi.org/10.1159/000134225

Lee, L. Y., Lee, D. T., & Woo, J. (2007). Effect of Tai Chi on state self-esteem and health-related quality of life in older Chinese residential care home residents. *Journal of Clinical Nursing*, *16*(8), 1580 - 1582. https://doi.org/10.1111/j.1365-2702.2007.02061.x

Leinaar, E., Alamian, A., & Wang, L. (2016). A systematic review of the relationship between asthma, overweight, and the effects of physical activity in youth. *Annals of Epidemiology*, *26*(7), 504 - 510. https://doi.org/10.1016/j.annepidem.2016.06.002

Leung, L. Y. ling, Chan, A. W. kiu, Sit, J. W. hung, Liu, T., & Taylor-Piliae, R. E. (2019). Tai Chi in Chinese adults with metabolic syndrome: A pilot randomized controlled trial. *Complementary Therapies in Medicine*, *46*(3), 54 - 61. https://doi.org/10.1016/j.ctim.2019.07.008

Li, H., Peng, F., Lyu, S., Ji, Z., Li, X., & Liu, M. (2023). Newly compiled Tai Chi (Bafa Wubu) promotes lower extremity exercise: a preliminary cross sectional study. *PeerJ*, *11*, e15036. https://doi.org/10.7717/peerj.15036

Lin, B., Jin, Q., Liu, C., Zhao, W., & Ji, R. (2022). Effect and mechanism of tai chi on blood pressure of patients with essential hypertension: a randomized controlled study. *Journal of Sports Medicine and Physical Fitness*, *62*(9), 1272 - 1277. https://doi.org/10.23736/S0022-4707.21.13394-8

Liu, J., Yeung, A., Xiao, T., Tian, X., Kong, Z., Zou, L., & Wang, X. (2019). Chen-style tai chi for individuals (Aged 50 years old or above) with chronic non-specific low back pain: A randomized controlled trial. *International Journal of Environmental Research and Public Health*, *16*(3), 1 - 9. https://doi.org/10.3390/ijerph16030517

Lohman, T. J., Roache, A. F., & Martorell, R. (1992). Anthropometric Standardization Reference Manual. *Medicine & Science in Sports & Exercise*, *24*(8), https://doi.org/10.1249/00005768-199208000-00020

Lyu, S., Zhang, J., Nie, J., Li, C., Gao, T., Yuan, W., ... Ma, J. (2020). Comparative study of physiologic characteristics between the newly compiled Bafa Wubu of tai chi and 24 form simplified tai chi. *BMC Sports Science, Medicine and Rehabilitation*, *12*(1), 1 - 7. https://doi.org/10.1186/s13102-020-00192-x

Nyman, S. R., Ingram, W., Sanders, J., Thomas, P. W., Thomas, S., Vassallo, M., ... Barrado-Martín, Y. (2019). Randomised controlled trial of the effect of tai chi on postural balance of people with dementia. *Clinical Interventions in Aging*, *14*, 2017 - 2029. https://doi.org/10.2147/CIA.S228931

Patel, R., Tu, B., & Gittner, L. S. (2023). The Use of Tai Chi and Qigong to Mediate Long-Haul COVID-19 Symptoms: Case Report. *Integrative Medicine Reports,* 2(1), 1 - 6. https://doi.org/10.1089/imr.2022.0086

Shou, X. L., Wang, L., Jin, X. Q., Zhu, L. Y., Ren, A. H., & Wang, Q. N. (2019). Effect of T'ai Chi Exercise on Hypertension in Young and Middle-Aged In-Service Staff. *Journal of Alternative and Complementary Medicine*, *25*(1), 73 - 78. https://doi.org/10.1089/acm.2018.0011

Sun, L., Zhuang, L. P., Li, X. Z., Zheng, J., & Wu, W. F. (2019). Tai Chi can prevent cardiovascular disease and improve cardiopulmonary function of adults with obesity aged 50 years and older: A long-term follow-up study. *Medicine, 98*(42), e17509. https://doi.org/10.1097/MD.0000000000017509

Speer, K. E., Semple, S., Naumovski, N., & McKune, A. J. (2020). Measuring Heart Rate Variability Using Commercially Available Devices in Healthy Children: A Validity and Reliability Study. *European Journal of Investigation in Health, Psychology and Education, 10*(1), 390 - 404. https://doi.org/10.3390/EJIHPE10010029

Ten Hoor, G. A., Kok, G., Peters, G. J. Y., Frissen, T., Schols, A. M., & Plasqui, G. (2017). The psychological effects of strength exercises in people who are overweight or obese: A systematic review. *Sports Medicine, 47*, 2069 - 2081. https://doi.org/10.1007/s40279-017-0748-5

Zhang, J., Gao, T., Li, Y., Song, Z., Cui, M., Wei, Q., ... Lyu, S. (2023). The effect of Bafa Wubu of Tai Chi on college students' anxiety and depression: A randomized, controlled pilot study. *Frontiers in Physiology*, *14*. https://doi.org/10.3389/FPHYS.2023.1036010

Receieved: 2024, May 7
Revised: 2024, October 24
Accepted: 2024, November 7

TNSU JOURNAL