

The Effect of Wai Tan Kung on Autonomic Nervous Modulation in the Elderly

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Key Words

Wai tan kung · Calisthenics · Exercise · Heart rate variability · Vagal modulation · Sympathetic modulation · Sympathetic reserve

Abstract

The decline in physical capacity in the elderly can be ameliorated by low-velocity, low-impact exercises. Wai tan kung (WTK), a traditional Taiwanese conditioning exercise, is suitable for older people. This study evaluated the effect of WTK on autonomic nervous modulation in the elderly. Twenty WTK practitioners and 20 normal controls were recruited in this study. The stationary state spectral heart rate variability (HRV) measures, hemodynamics, and spirometry between the WTK group and normal controls and sequential changes in HRV measures and hemodynamics after WTK were compared. We found that the standard deviation and coefficient of variation of RR intervals, total power, low frequency power (LFP), and normalized LFP (nLFP) in WTK practitioners before WTK were all significantly higher than those of normal controls. After WTK, the normalized high-frequency power increased (nHFP) significantly from 27.7

± 13.2 normalized units (nu) before WTK to 37.6 ± 16.0 nu 30 min after WTK, and to 39.8 ± 20.1 nu 60 min after WTK. In contrast, LFP/HFP decreased significantly from 1.3 ± 1.0 before WTK to 1.0 ± 0.9 30 min after WTK and to 0.8 ± 0.6 60 min after WTK. We concluded that in the short term, WTK enhances vagal modulation and suppresses sympathetic modulation, whereas in the long term, WTK enhances sympathetic modulation without compromising vagal modulation of the elderly. Thus WTK is good health-promoting calisthenics that can be recommended to the elderly.

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Introduction

Aging is associated with declines in physical capacity and the development of many chronic diseases. Preventive care for the elderly has received increased attention because of rapid increases in elderly populations in many countries and their disproportionately high medical expenses [7].

Vagal modulation is known to decrease in various physiological and pathological conditions, such as aging

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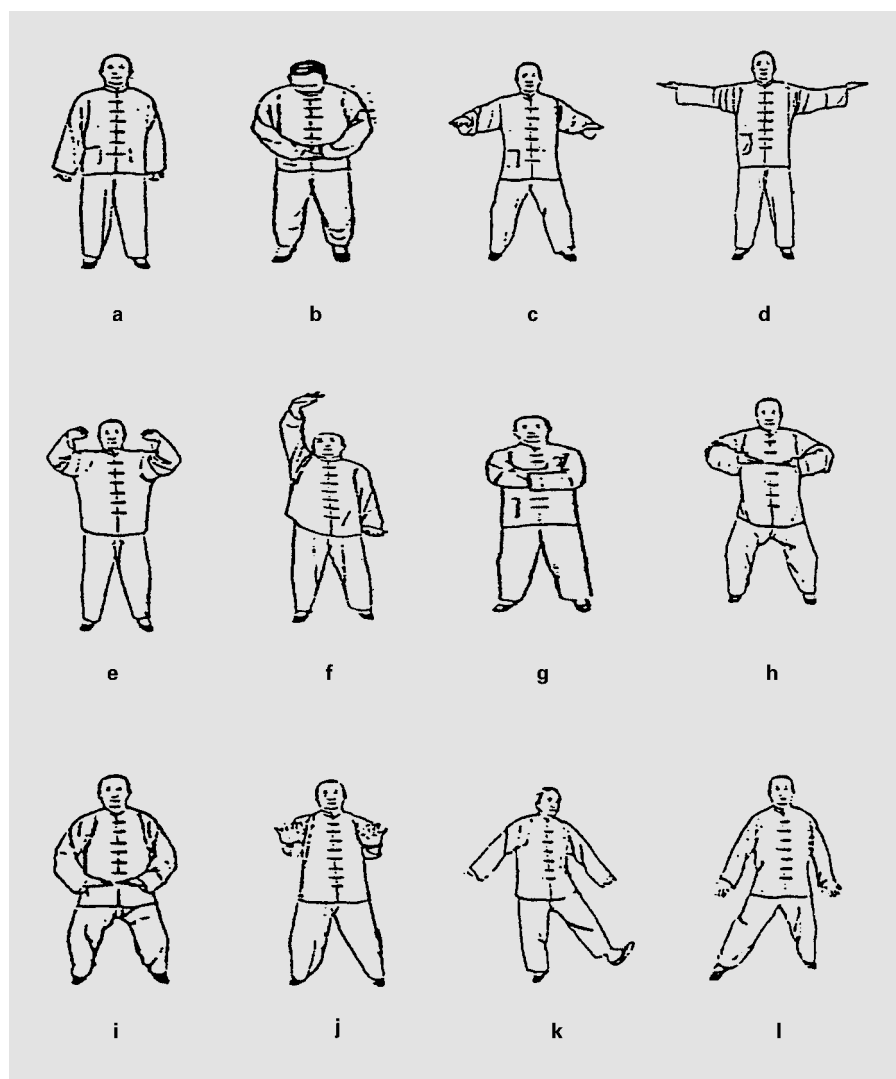


Fig. 1. Typical WTK postures and movements. **a** Preliminary movement. **b** Tortoise respiration. **c** Front and back hand thrusting. **d** Horizontal arm fluttering. **e** First circling. **f** Vertical arm stretching. **g** Crossed-arms trembling. **h** Leveled palm lifting. **i** Waist turning. **j** Body trembling. **k** Left leg trembling. **l** Right leg trembling.

[16], acute myocardial infarction [18], diabetes mellitus [17], chronic renal failure [1], or congestive heart failure [22]. As an integral part of most cardiac rehabilitation programs, regular exercise can remodel the cardiovascular system and modify the autonomic nervous control [14]. For instance, handgrip exercise is one of the physiological means to increase vagal modulation of normal subjects [12]. Thus, it was suggested that supervised exercise in the elderly should emphasize aerobic, strength, and flexibility training [6]. However, lack of exercise is common in the senior population.

For the elderly, low-velocity, low-impact exercises are preferred to reduce their cardiovascular and orthopedic complications [3]. Goble et al. [9] reported that lower-intensity exercise might have training effects similar to

those of higher-intensity exercise for cardiac patients. For patients after acute myocardial infarction referred for cardiac rehabilitation, both low- and high-intensity exercise training have been shown to improve the functional capacity and produce relatively similar changes in cardiorespiratory variables during the initial 3 months of exercise training [5]. Therefore, low-intensity exercise might be more suitable for unfit and elderly patients than would other kinds of exercise.

Owing to their low intensity, easy accessibility, low cost, and appropriateness for implementation in the community, some Oriental conditioning exercises deserve attention [28]. Among many Oriental conditioning exercises, wai tan kung (WTK) (fig. 1) deserves special consideration because it is a traditional Taiwanese conditioning

exercise that is said to be suitable for elderly people and patients with chronic diseases [8]. Closely related to chi kung, WTK is more complex, demands a wider range of motion, has more applications in traditional Oriental medicine, and can improve balance, kinesthetic sense, and muscular strength [8]. Unfortunately, there is no scientific study on WTK in the literature.

Since there are many WTK practitioners in Oriental countries in addition to Taiwan, it would be interesting to investigate the physiological effects of WTK on the elderly. Thus, the aim of this study was to examine the effect of WTK on autonomic nervous modulation in the elderly using spectral heart rate variability (HRV) analysis.

Materials and Methods

Study Subjects and Study Design

Both WTK practitioners and normal subjects who did not practice WTK were included in this study. WTK practitioners were recruited from a WTK training center in Taiwan, and normal subjects without WTK experience were recruited from the community. All subjects had a normal lifestyle, and were capable of accomplishing daily activities without limitations. The Institute Review Board of Taipei Veterans General Hospital approved this study. The procedure was fully explained to the subjects, and informed written consent was obtained from each subject before the study. Subjects who had major cardiopulmonary disease or were on regular medicine for diabetes mellitus, hypertension, or renal or liver disease were excluded from the study.

Subjects included in this study were instructed not to take caffeinated or alcoholic beverages for at least 24 h prior to the study. Before WTK, a subject was instructed to lie down and rest in a supine position. After a 5-min rest, the trend of conventional lead II electrocardiographic signals was recorded by a Vital Signs Monitor (BCI International, Waukesha, Wisc., USA) and transferred to a personal computer for storage and later analysis. After baseline recording, the subject was advised to exercise by doing WTK for 40 min. Each session of WTK began with 5 min of preliminary movements that included relaxing the entire body without exerting any strength, breathing naturally, and keeping the mind calm. The tip of the tongue touches the ridge behind the upper teeth, and the eyes look ahead in a relaxed manner during 30 min of WTK movements and 5 min of chi-releasing movements (the small crane step). Each WTK routine includes 12 postures [8]. During WTK exercise, the subject maintained the same pace in exercising the postures of WTK in sequence by performing these postures according to a pre-recorded tape to ensure that the same pace and sequence of postures were followed by all WTK practitioners. Thirty and 60 min after completion of the WTK routine, the second and the third trends of ECG signals were recorded using the same methodology. All procedures were performed in a bright, quiet room with a constant temperature of 24–25°C.

A resting standard 12-lead electrocardiogram (ECG), spirometry (IQmark Digital ECG and Digital Spirometer, Brentwood Medical Technology Corp., Torrance, Calif., USA), blood pressure measurement (Kenlu model K-300 sphygmomanometer), and an arterial O₂

saturation measurement (Vital Signs Monitor, BCI) were performed on each subject in the WTK group at each session and on the controls.

Equipment and Measurements

The sampling frequency for ECG recording was 200 Hz. The R-wave-detecting software was used to identify peaks in the R waves in the recorded ECG signals and to measure consecutive RR intervals. Sinus pauses and arterial or ventricular arrhythmia were deleted, and the last 512 stationary RR intervals in each session were obtained for spectral HRV analysis.

The mean, standard deviation (SD_{RR}), and coefficient of variation (CV_{RR}) of the 512 stationary RR intervals were calculated using standard formulae for each subject. The power spectra of RR intervals were obtained by means of fast Fourier transformation (Mathcad 2001, MathSoft Inc., Cambridge, Mass., USA). The direct current component was excluded before calculating the power. The area under the curve of the spectral peaks within the range of 0.01–0.4 Hz was defined as the total power (TP); the area under the spectral peaks within the range of 0.01–0.04 Hz was defined as the very-low-frequency power (VLFP); the area under the spectral peaks within the range of 0.04–0.15 Hz was defined as the low-frequency power (LFP), and the area under the spectral peaks within the range of 0.15–0.40 Hz was defined as the high-frequency power (HFP). The normalized HFP ($nHFP = HFP/TP$) was used as an index of vagal modulation, the normalized LFP ($nLFP = LFP/TP$) as an index of sympathetic and vagal modulation, the LFP/HFP as an index of sympathovagal balance [21], and the normalized VLFP ($nVLFP = VLFP/TP$) as an index of the renin-angiotensin-aldosterone system and vagal withdrawal of the subject [24]. The frequency at which the high-frequency peaks occurred in the power spectrum of RR intervals was used as the respiration rate or breathing frequency [21].

Statistical Analysis

The Mann-Whitney rank sum test (SigmaStat statistical software, SPSS Inc., Chicago, Ill., USA) was employed to compare the baseline characteristics and HRV measures in both time and frequency domains between WTK practitioners and normal controls. Friedman repeated-measures analysis of variance on ranks was performed to compare the HRV measures among before WTK, 30 min after WTK, and 60 min after WTK, with statistical significance set as $p < 0.05$. The Wilcoxon signed rank test with Bonferroni correction was employed in the 3 pairwise comparisons among values for before WTK, 30 min after WTK, and 60 min after WTK, where the statistical significance was set as $p < 0.017$. Linear regression analysis was used to assess the linear relationship between the breathing frequency, WTK experience, and HRV measures. $p < 0.05$ was considered statistically significant. All data are presented as the mean \pm SD.

Results

Baseline Characteristics

Twenty WTK practitioners and 20 normal controls were included in this study. The years of WTK experience were not correlated with the measures of HRV. There were 9 men and 11 women in the study group, and 5 men and 15 women in the control group. There were no signifi-

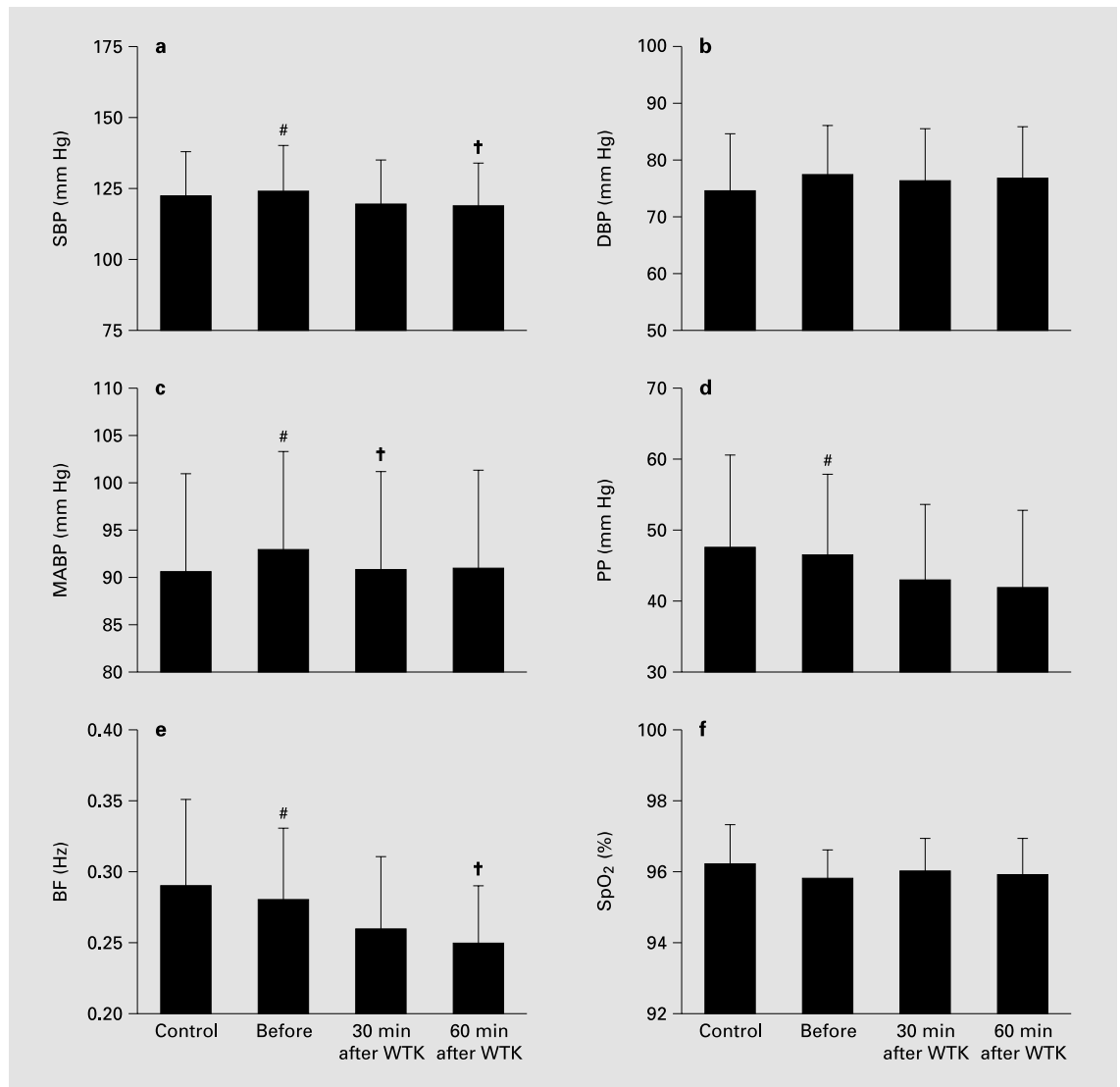


Fig. 2. Sequential changes in hemodynamics after WTK. Data are presented as the mean \pm SD. # $p < 0.05$ among values for before WTK, 30 min after WTK, and 60 min after WTK (Friedman repeated-measures ANOVA); † $p < 0.017$ vs. before WTK (Wilcoxon signed rank test with Bonferroni correction). **a** Systolic blood pressure (SBP). **b** Diastolic blood pressure (DBP). **c** Mean arterial blood pressure (MABP). **d** Pulse pressure (PP). **e** Breathing frequency (BF). **f** Arterial O₂ saturation determined by pulse oximeter (SpO₂).

cant differences in HRV measures between male and female WTK practitioners. The WTK practitioners had practiced WTK calisthenics at least 1 h each time, 3 times per week for an average length of 5.6 ± 6.0 years. Table 1 tabulates the baseline characteristics of the normal controls and WTK practitioners. There were no significant differences in the age, gender, body weight, body height, body mass index, forced vital capacity, forced expiratory volume in the first second, or the ratio of forced expirato-

ry volume in the first second to the forced vital capacity between normal controls and WTK practitioners, except for the length of WTK training.

Comparisons between WTK Practitioners and Controls

Figure 2 shows the sequential changes in the hemodynamics after WTK. There were no significant differences in the systolic blood pressure, diastolic blood pressure,

Table 1. Baseline characteristics of WTK practitioners and normal controls

Baseline characteristic	Normal controls (n = 20)	WTK practitioners (n = 20)
Age, years	55.9 ± 8.3	58.1 ± 5.9
Gender, M/F	5/15	9/11
Body weight, kg	59.5 ± 8.5	61.1 ± 9.3
Body height, cm	156.4 ± 7.0	161.3 ± 10.0
BMI, kg/m ²	24.3 ± 2.2	23.4 ± 2.2
Length of WTK practice, years	0.0	5.6 ± 6.0*
FVC, liters	2.7 ± 0.7	3.1 ± 0.7
FVC, %	108.5 ± 18.2	99.6 ± 17.3
FEV ₁ , liters	2.1 ± 0.6	2.3 ± 0.6
FEV ₁ , %	104.2 ± 23.8	93.0 ± 17.7
FEV ₁ /FVC, %	78.5 ± 8.6	76.4 ± 7.3

FVC = Forced vital capacity; FEV₁ = forced expiratory volume in the first second; BMI = body mass index; bpm = beats per minute. Data are shown as the mean ± SD.

* p < 0.05 when comparing the WTK group with the control group (Mann-Whitney rank sum test).

mean arterial blood pressure, pulse pressure, breathing frequency, or arterial O₂ saturation between normal controls and WTK practitioners before WTK.

Figure 3 shows the sequential changes in the time-domain HRV measures after WTK; figure 4 shows the sequential change in the frequency-domain HRV measures after WTK. The SD_{RR}, CV_{RR}, TP, LFP, and nLFP of the WTK practitioners before WTK were all significantly higher than those of the normal controls.

Short-Term Effects of WTK on Autonomic Modulation

After WTK, the systolic blood pressure, mean arterial blood pressure, pulse pressure, breathing frequency, and heart rate all significantly and gradually decreased (fig. 2, 3), while the mean RR interval significantly and gradually increased. In the frequency domain, the nHFP increased significantly from 27.7 ± 13.2 normalized units (nu) before WTK to 37.6 ± 16.0 nu 30 min after WTK and to 39.8 ± 20.1 nu 60 min after WTK (fig. 4). In contrast, the LFP/HFP significantly decreased from 1.3 ± 1.0 before WTK to 1.0 ± 0.9 30 min after WTK, and to 0.8 ± 0.6 60 min after WTK (fig. 4). Similarly, the nVLFP significantly decreased from 38.4 ± 12.7 nu before WTK to 30.9 ± 11.5 nu 30 min after WTK, and to 30.7 ± 15.6 nu 60 min after WTK (fig. 4).

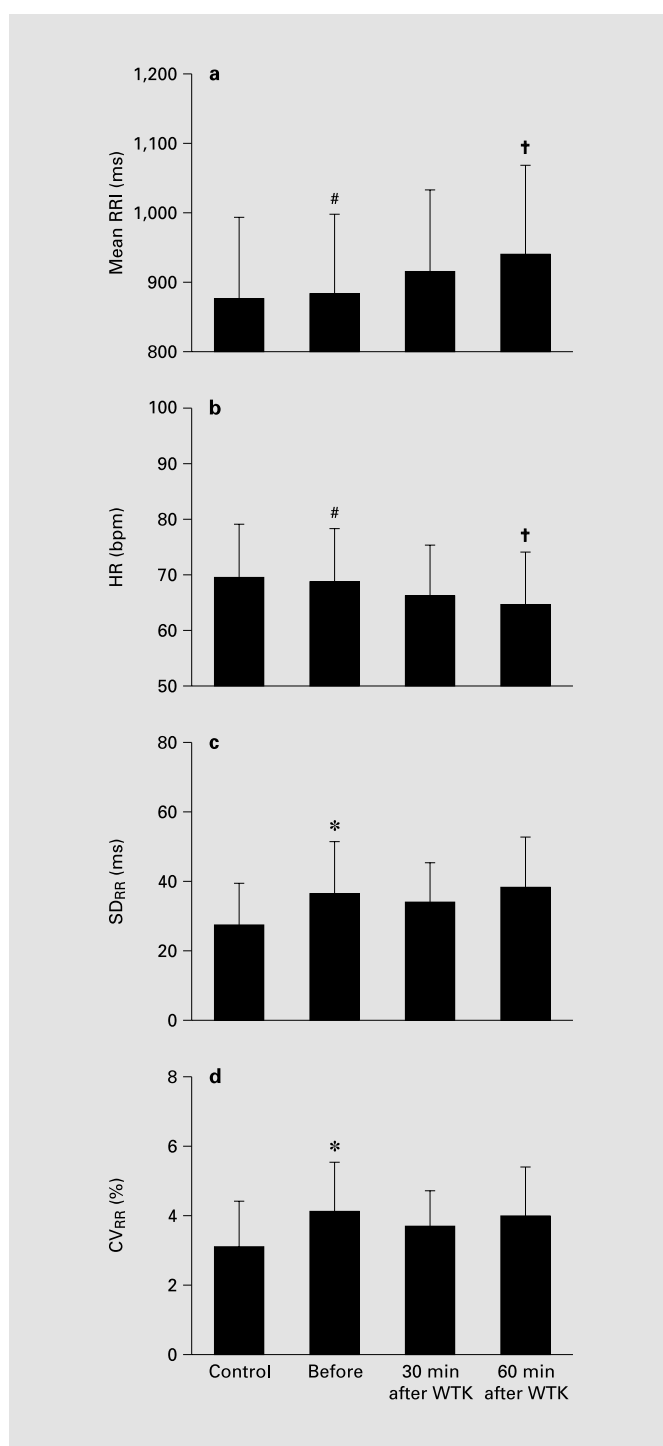


Fig. 3. Sequential change in time domain HRV measures after WTK. Data are presented as the mean ± SD. * p < 0.05 vs. the controls (Mann-Whitney rank sum test); # p < 0.05 among values for before WTK, 30 min after WTK, and 60 min after WTK (Friedman repeated-measures ANOVA); † p < 0.017 vs. before WTK (Wilcoxon signed rank test with Bonferroni correction). **a** Mean RR interval. **b** Heart rate (HR). **c** Standard deviation of RR (SD_{RR}). **d** Coefficient of variation of RR (CV_{RR}).

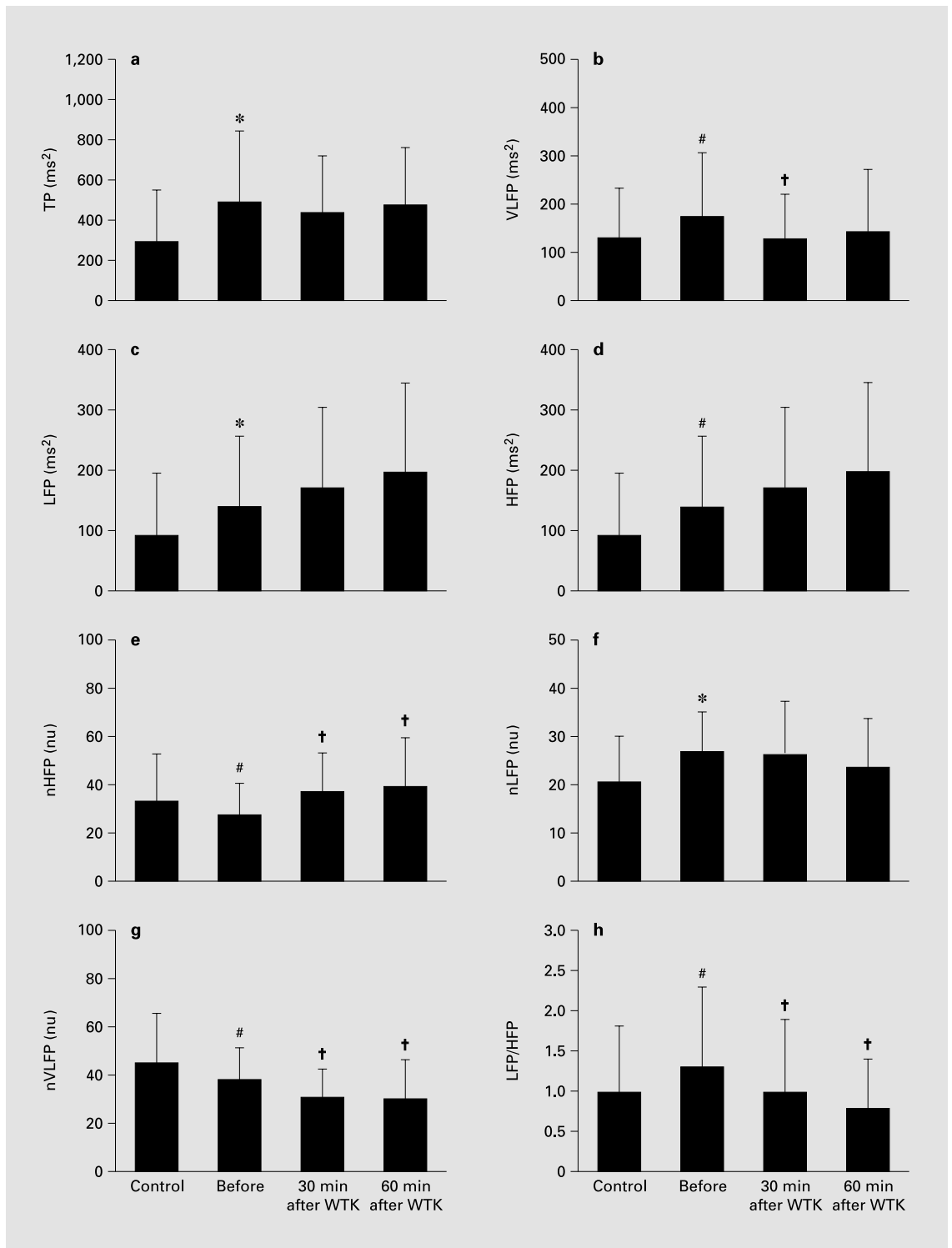


Fig. 4. Sequential changes in frequency domain HRV measures after WTK. Data are presented as the mean \pm SD. * $p < 0.05$ vs. the controls (Mann-Whitney rank sum test); # $p < 0.05$ among values for before WTK, 30 min after WTK, and 60 min after WTK (Friedman repeated-measures ANOVA); † $p < 0.017$ vs. before WTK (Wilcoxon signed rank test with Bonferroni correction). **a** Total power (TP).

b Very-low-frequency power (VLFP). **c** Low-frequency power (LFP). **d** High-frequency power (HFP). **e** Normalized high-frequency power (nHFP). **f** Normalized low-frequency power (nLFP). **g** Normalized very-low-frequency power (nVLFP). **h** Low-/high-frequency power ratio (LFP/HFP).

Discussion

WTK is a traditional Taiwanese mind-body exercise that is unique due to its use of whole-body trembling and coordinated movements. The basic principle of WTK exercise is to get rid of distracting ideas and allow one's inner energy to rise up automatically from inside and make the whole body tremble by itself. WTK consists of a sequence of 12 postures that are smooth, harmonic, and relaxing [8]. WTK is performed in sequence with varying degrees of trembling and relaxation of various groups of muscles. During WTK exercise, the body is constantly trembling from feet to fingers and head, while deep and slow breathing and mental concentration are required to achieve harmony between the body and the mind [8]. Thus, WTK can fill the internal organs with original chi or energy, relax the muscles, improve the blood circulation, strengthen the muscles, smoothly increase stamina, and ultimately enable one to become healthy and happy.

Since WTK might improve the cardiopulmonary function, it is worthwhile comparing the cardiopulmonary function between WTK practitioners before WTK and normal controls. Although many traditional measures of cardiopulmonary function did not significantly differ between WTK practitioners before WTK and normal controls, many HRV measurements such as SD_{RR} , CV_{RR} , TP, LFP, and nLFP of WTK practitioners before WTK were all significantly higher than those of normal controls. These results suggest that HRV measures are more sensitive than traditional measures of cardiopulmonary function, and that the accumulated or long-term effect of WTK is to increase the low-frequency components without compromising the high-frequency components of the HRV in WTK practitioners.

WTK practitioners regulate their respiration in accordance with their body movements during WTK practice, because WTK is a kind of Taoist kung fu [8]. Therefore, one would suspect that the increased low-frequency components of HRV might be caused by the controlled respiration of WTK practitioners. To see if the observed increase in the low-frequency components of HRV in WTK practitioners before WTK was caused by their controlled respiration, it was necessary to compare the respiratory frequencies of WTK practitioners and controls. The respiratory frequency was not recorded during this study. However, it could be obtained because the frequency at which the high-frequency peaks occurred in the power spectrum of RR intervals is the respiration rate or breathing frequency of the subject [21]. By comparing the breathing frequencies of WTK practitioners before WTK,

30 min after WTK, and 60 min after WTK with those of the controls, we found that only the breathing frequency 60 min after WTK was significantly lower than that of the controls. However, the regression analysis showed that the breathing frequency was not significantly correlated with any HRV measure after WTK. Thus, the decrease in respiratory rate 1 h after WTK might be caused by the intentional regulation of respiration by WTK practitioners, but the increase in vagal modulation and the decrease in sympathetic modulation after WTK might not be caused by respiration itself.

Our analysis shows that the length of WTK experience was not correlated with HRV measures. It seems probable that many factors, such as the physical status of the subjects, their devotion to WTK practice, their skill and level of sophistication, as well as the length of WTK experience would affect the autonomic nervous modulation of WTK practitioners. This might be the reason why the length of WTK experience was not correlated with HRV measures.

Amano et al. [2] studied exercise training and autonomic nervous system activity in obese individuals. They found that 12 weeks of exercise training significantly improved both sympathetic and vagal modulations. Pigozzi et al. [20] showed that exercise training was able to induce an increase in the sympathetic modulation of the sinus node that may coexist with signs of relatively reduced, or unaffected, vagal modulation. In accordance with those 2 studies, we found that the index of the sympatho-vagal balance and vagal withdrawal of WTK practitioners were significantly higher than those of normal controls, while the vagal modulation of WTK practitioners did not significantly differ from that of normal controls. Our observations suggest that the long-term or cumulative effect of WTK on autonomic nervous modulation might be an increase in sympathetic modulation without compromising the vagal modulation.

Although the heart rate, systolic blood pressure, and diastolic blood pressure of WTK practitioners before WTK did not differ from those of normal controls, sympathetic modulation was increased in WTK practitioners before WTK. It seems that the heart rate, systolic blood pressure, and diastolic blood pressure are not modulated solely by sympathetic activity, but that vagal activity is also involved in their modulation. This is true because both the heart rate and blood pressure are controlled by the autonomic nervous system which has 2 major divisions: the sympathetic nervous system and the parasympathetic nervous system. The parasympathetic system generally produces effects opposite to those of the sympathetic division. The effects of sympathetic stimulation

include increased heart rate, cardiac contractility and blood pressure, allowing better perfusion of muscles and improving the return of venous blood to the heart [27]. On the other hand, the parasympathetic system has a depressant effect on the heart through the vagus nerve (cranial nerve X). It slows impulse conduction and thus decreases the heart rate [27]. The vagal activity of WTK practitioners before WTK not being decreased might be one of the reasons why the heart rate, systolic blood pressure, and diastolic blood pressure did not differ from those of normal controls in this study.

The clinical significance of our observations and those of Amano et al. [2] and Pigozzi et al. [20] can be realized referring to the study by Yien et al. [25] which showed that progressive increases in power spectral density values of very-low-frequency and low-frequency components of systemic arterial pressure and heart rate signals of patients in an intensive care unit appeared to be related to recovery, and that progressive decreases in power spectral density values of these spectral components were indicative of fatality. Thus, WTK might be beneficial to the elderly because an average of about 5.6 years' WTK training could significantly improve sympathetic modulation without compromising vagal modulation in these elderly adults.

Hull et al. [11] demonstrated that chronic exercise not only increases HFP, but also prevents ventricular fibrillation during acute myocardial ischemia. Goldsmith et al. [10] indicated that physical fitness is highly correlated with vagal modulation as measured by HFP. Kurita et al. [12] demonstrated that in normal subjects, LFP/HFP does not significantly change during handgrip exercise, but HFP significantly increases. Wilmore and Costill [27] also stated that while the sympathetic system predominates during times of physical or emotional stress when body demands are higher, the parasympathetic system again predominates after the stress subsides. In accordance with those reports, we found that the short-term effect of WTK exercise was to enhance vagal modulation and to lower sympathetic modulation. This is comprehensible since WTK exercise might deplete some of the sympathetic reserve of a subject, leading to the observed increase in cardiac vagal modulation and to increased sympathetic modulation. Because of repeated depletion of some of the sympathetic reserve by repeated sessions of WTK, the sympathetic reserve might be stimulated to increase in the long run. This might be the reason why sympathetic modulation is increased in WTK practitioners as compared to controls, similar to what has been found with other aerobic exercises.

The term 'sympathetic reserve' has previously been mentioned in several studies [4, 13, 19, 23, 26]. The concept of sympathetic reserve can be used here to explain the change in autonomic nervous modulation after WTK exercise. The sympathetic efferent activity is determined by a complex interaction of neurons in the spinal cord, medulla, pons, hypothalamus, limbic system, and portions of the forebrain and by feedback signals arising from cardiovascular mechano- and chemoreceptors localized in discrete baroreceptor centers in the carotid sinuses, aortic arch, and heart [15]. Some mediators increase as an expression of an increased sympathetic outflow to the end effector organs such as nerves of the exercise end plate. A large amount of epinephrine and a smaller amount of norepinephrine are released from the adrenal medulla in response to activation of sympathetic preganglionic afferents during intense sympathetic activation, resulting in markedly increased blood pressure and significantly redistributed cardiac output (e.g., simultaneously increased perfusion of skeletal muscle and decreased splanchnic flow). Therefore, the 'sympathetic reserve' might be conceived as the 'reservoir of sympathetic mediators' or the 'capacity of the sympathetic nervous system to release sympathetic mediators'.

In conclusion, we found that the short-term effect of WTK was to enhance vagal modulation and to suppress sympathetic modulation in the elderly, while the long-term effect of WTK was to increase sympathetic modulation without compromising vagal modulation. Since aging is associated with decreased vagal activity, WTK might be good health-promoting calisthenics worthy of recommendation to the elderly in terms of its autonomic nervous modulation.

Acknowledgments

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