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# Comparing the Changes in Blood Pressure After Acute Exposure to Tai Chi and Walking

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ABSTRACT

***International Journal of Exercise Science 12(3): 77-87, 2019.*** Hypertension is a major health concern throughout the United States and is a major cause of cardiovascular disease. The purpose of this study was to compare the responses of Tai Chi and walking on measures of central and peripheral cardiac mechanisms when controlling for exercise intensity. Fifteen hypertensive subjects (2 males, 13 females; age = 20.7 ± 3.77 years; body fat = 24.26 ± 10.27%) participated in Tai Chi (TC) and walking (WK) for 30 minutes on non-consecutive days. Central systolic (CSBP) and diastolic blood pressure (CDBP), augmentation index (Alx), pulse pressure (PP), heart rate (HR), and brachial systolic (BSBP) and diastolic blood pressure (BDBP) were measured prior to exercise and following exercise every 10 minutes for a total of 60 minutes in a seated position. There were no significant differences between the two exercise forms. CSBP decreased 10 minutes after exercise in both exercise types (TC = 6.63 ± 3.258 mmHG; WK = 7 ± 4.144 mmHG $p < 0.05$), and 40 minutes after exercise in both exercise types (TC = 6.07 ± 3.33 mmHG; WK = 8.2 ± 3.15 mmHG, $p < 0.05$) compared to the initial measurement. BSBP also decreased in both exercise forms following 10 min of rest (TC = 6.99 ± 3.776 mmHG; WK = 8.8 ± 3.20 mmHG $p = 0.05$), and 40 min (TC = 8.46 ± 3.07 mmHG; WK = 8.87 ± 3.87 mmHG, $p < 0.05$) when compared to the initial resting measurement. Central aortic pressure exhibits a post exercise hypotensive (PEH) effect similar to that of peripheral blood pressure. Both Tai Chi and walking elicited similar PEH effects on systolic blood pressure in hypertensive individuals.

KEY WORDS: Exercise, hemodynamics, acute

## INTRODUCTION

Hypertension is a major health concern throughout the United States and is a major cause of cardiovascular disease (7). Hypertension affects 77.9 million people in the United States and 1 billion people throughout the world (20). Out of these hypertensive patients, only 54% have blood pressure under control (2, 4). The combination of the high prevalence of hypertension with a lack of control contributes to hypertension becoming a major health concern. In addition, hypertension is a major risk factor of stroke and cardiovascular disease and is associated with atherosclerosis and diabetes (2, 4). Possible reasons for this lack of control is cost of treatment and attrition of lifestyle interventions. Thus, it is imperative that proper intervention strategies and methods be determined to treat hypertension and elicit blood pressure reduction.

Exercise has been shown to cause post-exercise-hypotension (PEH) in brachial blood pressure leading to an acute drop in blood pressure (3). However, little information is known about which exercise form causes the greatest PEH response and if PEH occurs in central pressure similar to brachial pressure (3, 12). In addition, recent research lays claim to the importance of central hemodynamic measurements as they better represent stress on the myocardium (17). When compared to peripheral measures, central pressure has been found to be a more accurate predictor of pressure on the myocardium and can be estimated non-invasively through pulse wave analysis (17, 18). Also, there is a rising clinical importance placed on measures of arterial stiffness as independent predictors of cardiovascular disease.

Tai Chi has become a frequently used modality of exercise that has been shown to improve a multitude of physiological measures (6). Tai Chi is a spiritual art that focuses on slow and fluid movements through a full range of motion focusing on balance, core strength, flexibility, and meditation techniques (24). Tai Chi is known for its beneficial effects on blood pressure when combined with other forms of lifestyle modifications (6, 16). However, the most frequently prescribed exercise for cardiovascular benefits is walking for 150 minutes per week (7). Walking has been shown to improve cardiovascular fitness in individuals and shows slight improvements in blood pressure following the exercise (13). However, the effects of walking on blood pressure and other hemodynamic mechanisms may not be similar to Tai Chi.

There has yet to be a study that compares walking and Tai Chi to determine their effects on blood pressure and other measures of cardiovascular performance in an acute setting. Thus, the purpose of this study was to compare the responses of Tai Chi and walking on measures of cardiovascular performance. Due to previous research, it was hypothesized that Tai Chi would have greater effects on all measures of blood pressure when compared to walking.

## METHODS

*Participants*

Following approval of the study from the Institutional Review Board of Springfield College (SC), participants were recruited through flyers and emails dispersed around the college campus. The inclusion criteria were; between the ages of 18-35, classified as hypertensive (systolic blood pressure greater than 130mmHG or a diastolic blood pressure greater than 90mmHG), currently on no blood pressure medication, and had no prior experience of Tai Chi, as research indicates prior practice of Tai Chi has long-term physiological benefits (23). Subjects were recruited through emails, class visits, and flyers placed around the SC campus. Measuring of blood pressure occurred on two separate occasions at the same time of day for accurate hypertensive measurement. The first blood pressure was used for preliminary measurement and the second being a confirmation of hypertension. If a subject did not meet the criteria for hypertension on the second measurement, they were excluded from the study. A sample size calculation was conducted with a power of .80, resulting in a requirement of 12 subjects to observe an effect.

*Protocol*
The study was designed to compare the acute responses of Tai Chi and walking with regard to measures of central and peripheral blood pressure, heart rate, central and peripheral pulse pressure, and augmentation index while controlling for exercise intensity. The independent variables were type of activity (Tai Chi or Walking) and time and were used as repeated factors. The primary outcomes included brachial blood pressure, central blood pressure, heart rate, pulse pressure, and augmentation index. This study used a repeated measures design and all measurements took place at the same time of day.

A total of two baseline measure visits and two interventions sessions were conducted for each subject. Subjects were asked to abstain from the consumption of caffeine or alcohol 12 hrs before the testing sessions. Subjects were asked to maintain normal dietary patterns, but otherwise diet was not controlled for. The first session was an introduction to the study that incorporated completion of the informed consent form in a seated position and the first blood pressure measurement was conducted following a 5-minute seated rest period. The second session included the second blood pressure measurement following a 5-minute rest period before estimation of body composition through the Bod Pod. Once the hypertensive diagnosis was met and body composition was estimated, the subjects were scheduled for the Tai Chi session first and the walking session second, with at least 48 hrs between each session. All measurements occurred during days 17-26 of the menstrual cycle to minimize the influence of the menstrual cycle. The subjects wore a heart rate monitor throughout the activity and rest periods. Blood pressure was measured before and immediately after the exercise and for 60 min following activity completion in a seated position at 10 min intervals in a resting position (for a total of 8 measurements).

The subjects participated in a 24 movement Tai Chi activity that was designed for use in college aged individuals (24). The subjects performed 30 min of the Tai Chi activity following a trained Tai Chi Instructor that was conducted in-person. Tai Chi was the first of the two activities in which the subject participated, the average heart rate recorded during the Tai Chi session was used to control exercise intensity of the walking. The second activity was walking at a brisk intensity to simulate a commonly prescribed exercise form for 30 min on a treadmill. The subject walked at an intensity matched to the Tai Chi exercise through matching the heart rate achieved from the Tai Chi session. Exercise forms had a heart rate intensity of 50.2% (3.5) of age predicted heart rate max for the Tai Chi, and 51.1% (4.9) for the walking. The average walking speed during the walking exercise for all subjects at 3.4 mph (0.4).

Body composition was estimated using the Bod Pod 5.20 (COS Med, Italy). The Bod Pod predicts body composition through using air displacement plethysmography (8). Body fat percentage is known as an indicator of fitness level and has been shown to be an effective predictor of body composition while being non-invasive with minimum risk (8).

Cardiovascular Function and Hemodynamics: Heart rate (HR) was monitored during both exercise forms and was used to match exercise intensity. Heart rate was measured using a standard heart rate monitor (Polar FT1; Finland) and HR has been shown to accurately predict exercise intensity (14). The AtCore Medical XCEL sphygmacor device (Atcore Med, USA) was utilized to measure peripheral and central blood pressure. Through pulse wave analysis, the device measured central pulse pressure and augmentation index (11). This device has been shown to be an effective non-invasive method to measure central pressures and arterial stiffness (11). In addition, the automated function of the device may reduce influence of bias in the blood pressure recordings.

*Statistical Analysis*

A sample size calculation was conducted with a power of .80, resulting in a requirement of 12 subjects to observe an effect. A total of six 2 (condition) x 8 (time) repeated measures analyses of variance (ANOVAs) were computed for all outcome measures. Repeated ANOAs were utilized in order to compare the testing conditions across all time points. All ANOVAs were followed with simple effects tests when the ANOVA was significant. IBM SPSS (Version 24.0) was used to compute all statistical analyses with the statistical significance level for each analysis set to 0.05. All analyses and post hoc comparisons were adjusted with a Bonferroni adjustment to account for making multiple comparisons.

## RESULTS

A total of 82 persons were contacted during recruitment for the study, with 17 subjects who underwent baseline testing. Out of the 17 subjects, 15 (13 female, 2 male) met the inclusion requirements and completed the study (2 female subjects were not classified as hypertensive). All 15 of the subjects had an average resting blood pressure greater than or equal to 120 mmHG or 80mmHG brachial blood pressure on two separate testing occasions and were between the ages of 18-35 years. Demographic and baseline data are reported in Table 1. A CONSORT diagram is displayed in Figure 1.

**Table 1.** Subject demographics and baseline characteristics.

| Variable | Mean | SD | Min | Max |
|---|---|---|---|---|
| Age (yrs) | 20.07 | 3.77 | 18 | 29 |
| Height (cm) | 164.25 | 9.30 | 150 | 183 |
| Weight (kg) | 69.40 | 17.57 | 46 | 102 |
| BMI (kg/m$^2$) | 25.71 | 5.70 | 18 | 37 |
| Body Fat % | 24.26 | 10.27 | 8 | 44 |
| SBBP (mmHG) | 131.13 | 14.49 | 110 | 163 |
| DBBP (mmHG) | 79.33 | 10.55 | 59 | 97 |
| SCBP (mmHG) | 114.80 | 11.97 | 96 | 138 |
| DCBP (mmHG) | 81.2 | 12.23 | 59 | 103 |

SCBP = systolic central blood pressure, DCBP = diastolic central blood pressure, SBBP = systolic brachial blood pressure, DBBP = diastolic brachial blood pressure. $N$ = 15

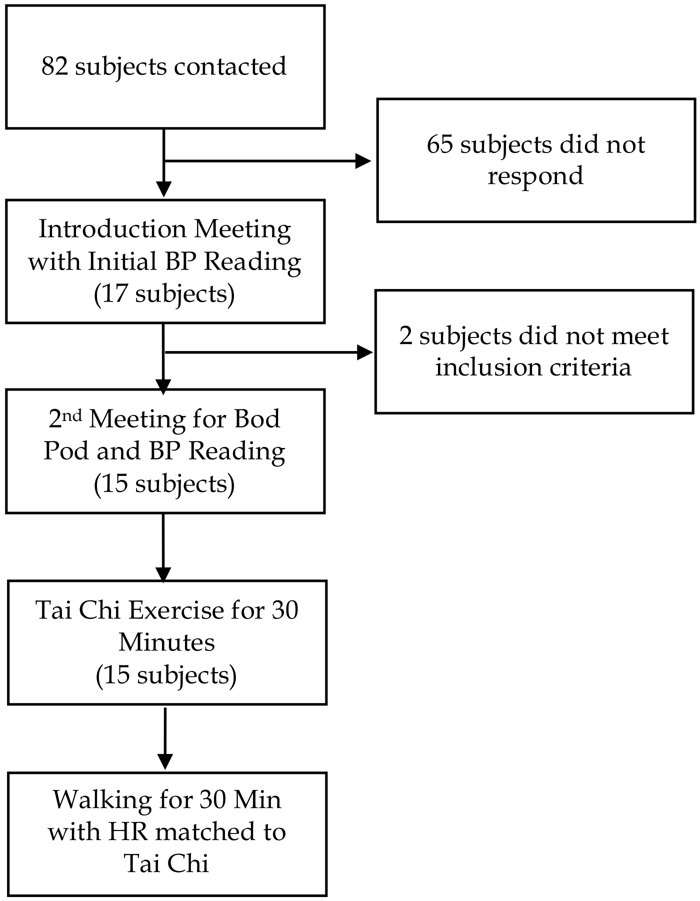


**Figure 1.** Flow chart showing subject recruitment and process through the study.

Systolic Central Blood Pressure (SCBP) showed a significant main effect for time ($F(7,98) = 13.65$, $p < 0.01$) with a reduction at 10 min of rest (6.67 mmHG, $p < .05$) and 40 min of rest (7.13 mmHG, $p = .05$) compared to the first resting measurement in both exercise forms. Changes in Central Aortic Pressure are displayed in Figure 2 across exercise conditions. However, there was no significant difference between exercise forms ($F(1,14) = 0.90$, $p = 0.90$). There was also no significant interaction between exercise type and time for SCBP ($F(7,98) = 0.37$, $p = 0.92$). Diastolic central blood pressure (DCBP) demonstrated a significant main effect for time ($F(7,98) = 2.89$, $p = 0.03$), but the exact location of this significance wasn't illuminated in the post hoc analysis ($p > 0.05$ for all comparisons). Also, there was no significant difference with the main effect exercise type, ($F(1,14) = 3.18$, $p = .10$). The interaction between exercise type and time was also not significant for DCBP ($F(7,98) = 1.11$, $p = 0.36$). SCBP and DCBP are demonstrated in Figures 3 & 4 as means and standard error. There were no significant differences for Augmentation Index for time ($F(7,98) = 3.19$, $p = 0.14$) and for exercise type ($F(1,14) = 1.47$, $p = .391$).

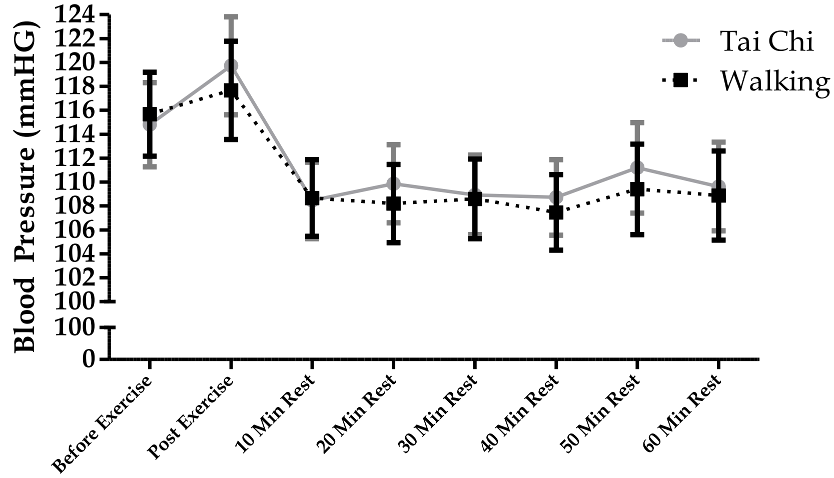


**Figure 2.** PEH responses in central aortic pressure over time following Tai Chi and Walking exercise throughout the resting periods. Data are means ± standard errors, $N = 15$.

A significant difference for the main effect time was observed in Systolic Brachial Blood Pressure (SBBP) ($F(2.8.,39.54) = 5.58$, $p < 0.01$). SBBP showed a significant reduction at 10 min (7.90 mmHG, $p = 0.05$), 20 min (8.40 mmHG, $p = 0.05$) and 40 min (8.87 mmHG, $p = 0.05$) when compared to the initial resting measurement. The means of SBBP are displayed in Figure 4. However, SBBP did not show a significant main effect for exercise type ($F(1,14) = 0.80$, $p = 0.78$). There was no significant interaction between exercise type and time for SBBP ($F(2.8.,39.54) = 1.11$, $p = 0.35$). The means of the testing occasions for Tai Chi and walking are shown in Figures 3 & 4.

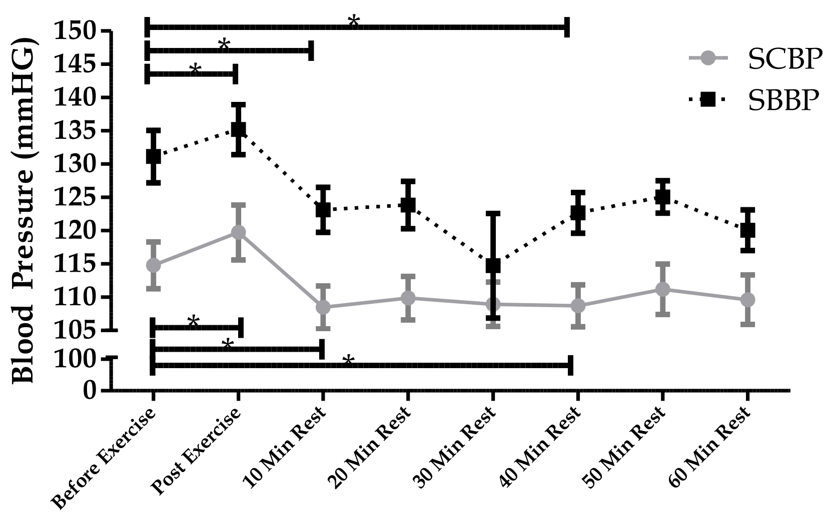


**Figure 3.** PEH responses in SCBP and SBBP over time following Tai Chi throughout the resting periods. SCBP = systolic central blood pressure, SBBP = systolic brachial blood pressure. Data are means ± standard errors, $N = 15$. * = $p < 0.05$ for comparison to rest measurement.

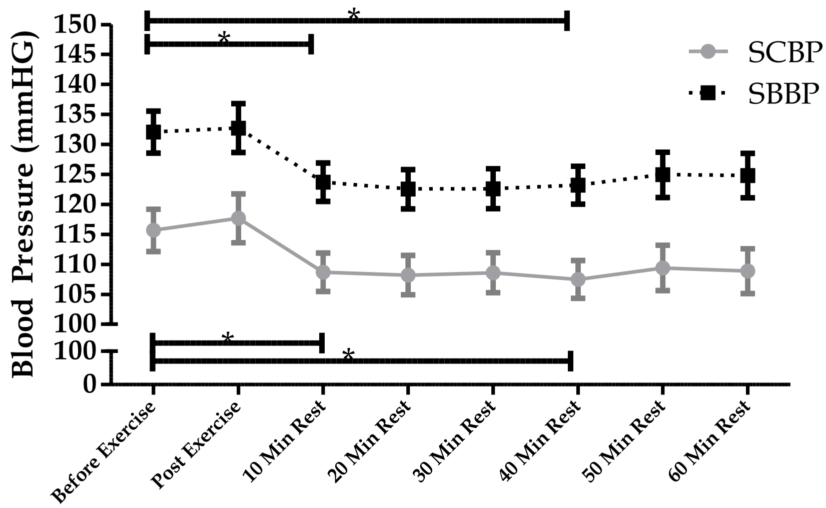


**Figure 4.** PEH responses in SCBP and SBBP over time following Walking exercise throughout the resting periods. SCBP = systolic central blood pressure, SBBP = systolic brachial blood pressure. Data are means ± standard errors, $N = 15$. * = $p < 0.05$ for comparison to rest measurement.

**Table 2**. Outcome measures over time in each exercise type.

| Variable | Rest | Post | 10 Min | 20 Min | 30 Min | 40 Min | 50 Min | 60 Min |
|---|---|---|---|---|---|---|---|---|
| Heart Rate | | | | | | | | |
| *Tai Chi* | 82.47 | 108.53* | 78.27* | 76.27 | 73.73 | 75.07 | 74.13 | 73.00 |
| | (13.97) | (17.05) | (12.49 | (13.26) | (12.31) | (12.96) | (13.42) | (13.95) |
| *Walking* | 79.13 | 103.13* | 80.67* | 77.93 | 78.40 | 75.07 | 75.33 | 76.07 |
| | (10.04) | (15.31) | (20.99) | (10.89) | (15.82) | (14.31) | (14.09) | (13.85) |
| Pulse Pressure | | | | | | | | |
| *Tai Chi* | 33.60 | 39.87 | 34.20 | 29.07 | 29.33 | 30.20 | 31.07 | 31.40 |
| | (11.98) | (13.22) | (19.48) | (9.76) | (10.08) | (11.47) | (10.27) | (10.04) |
| *Walking* | 38.07 | 32.27 | 31.67 | 30.13 | 30.93 | 34.53 | 31.20 | 32.20 |
| | (12.74) | (13.90) | (11.37) | (11.83) | (11.21) | (10.84) | (11.61) | (10.99) |
| Augmentation Index | | | | | | | | |
| *Tai Chi* | 8.53 | 9.00 | 11.60 | 6.20 | 7.33 | 8.93 | 6.53 | 5.30 |
| | (9.53) | (15.53) | (14.05) | (15.28) | (15.41) | (13.73) | (12.96) | (12.69) |
| *Walking* | 10.46 | 13.92 | 8.76 | 9.08 | 7.61 | 1.80 | 4.07 | 9.76 |
| | (20.25) | (21.96) | (16.64) | (17.23) | (14.73) | (14.46) | (15.29) | (11.99) |

Summary data for Heart Rate, Pulse Pressure, and Augmentation Index across all measurement time points. Data are presented as mean (standard deviation), $N = 15$. * = $p < 0.05$ for comparison to rest measurement.

There was a significant interaction between exercise type and time for Heart Rate ($F(4,56.7) = 2.43$, $p = .05$). Follow-up simple effects tests with Bonferroni adjustment indicated a trend that heart rate was lower during the Tai Chi rest periods during the 30$^{th}$ min rest period and the 60$^{th}$ min rest period compared to the Walking (73.63 bpm vs 78.40 bpm, $p = .05$; 73.0 bpm vs 76.0 bpm, $p = 0.06$). The means of heart rate in Tai Chi and Walking are reported in Table 3 and Figure 2. There was a significant difference in heart rate for the main effect time for both exercise forms ($F(2.5.35.1) = 44.93$, $p < 0.01$). The means of heart rate in both exercise forms are reported in Table

2. There was no significant difference for the main effect of exercise type in measures of heart rate ($F(1,14) = 0.23$, $p = 0.64$).

Pulse pressure was found to significantly increase following both activities during the post exercise measurement. The means of pulse pressure are presented in Table 2 across the 8 time points. However, there was no significant finding with regard to the main effect of exercise type ($F(1,14) = 1.14$, $p = 0.31$). There was also no significant interaction between exercise type and time for pulse pressure ($F(2.2,30.7) = 0.69$, $p = 0.52$). The pulse pressure means in each exercise type are presented in Table 2.

**DISCUSSION**

To the author's knowledge, this was the first study to observe post exercise hypotension (PEH) following an acute bout of Tai Chi. PEH is a physiological phenomenon describing a decrease in blood pressure seen following exercise and has been confirmed in other forms of activity such as walking and cycling (12). In addition, this study was one of the first studies to examine how central blood pressure changes with acute exercise after exposure to Tai Chi. The results of the study indicate that central blood pressure exhibits a similar PEH effect when compared to brachial blood pressure and that Tai Chi and walking illicit similar PEH responses following the activity.

The majority of studies examining PEH incorporate mean arterial pressure as the primary outcome measure (3, 12, 15). In this study PEH was confirmed in both brachial systolic blood pressure and central systolic blood pressure. PEH has been attributed to alterations in cardiac output and/or systemic vascular resistance (5, 9). The underlying cause of the changes in peripheral resistance and cardiac output are still disputed and could be due to any combination of changes in baroreceptors, hormones, or efferent nerve activity (12).

One of the possible mechanisms for PEH could be related to changes in heart rate (10). Although the literature is inconclusive, PEH is generally accompanied by an increase in sympathetic activity (to possibly offset the hypotensive response). This was not observed in this study, as heart rate significantly decreased during the resting periods. This reduction in heart rate in Tai Chi could have been caused by Tai Chi's impact on increasing parasympathetic nervous system activity similar to meditative techniques (19). Another possible explanation for the BP reduction are changes to baroreceptors, although this is also inconclusive (9). Baroreceptors are stretch receptors in smooth muscle that act to send signals to the brain in order to elicit changes in blood pressure that occur due to changes in stretch (9). Some research indicates that baroreceptor sensitivity following exercise changes, but these changes are likely to counteract the hypotensive effect. There is some evidence to suggest that the changes in catecholamines following exercise could influence PEH (5). Since hypertensive individuals have increased sympathetic nerve activity during rest, a reduction in the concentration of circulating catecholamines following exercise could result in PEH that has been hypothesized by others (10). However, catecholamines were not measured during this study. The changes in vascular sensitivity and nitric oxide seem to be another mechanism for PEH (10). Research in animals indicates that reduced alpha adrenergic tension was decreased due to nitric oxide (12). Although Halliwall and colleagues (10) reported that arterial pressure and resistance decreased without the presence of nitric oxide, nitric oxide is still considered to be a possible cause of PEH. Although the exact mechanism and cause of PEH is unknown, its effects have been confirmed in multiple exercise forms and PEH is one of the primary reasons exercise is prescribed for hypertensive and hypertensive patients.

Another interesting finding in this study was the comparison between central and brachial blood pressure. Utilizing brachial blood pressure, subjects averaged a blood pressure of 131.1(14.5) / 79.3 (10.6) compared to 114.8(12.0) / 81.2 (12.2). These results indicate that although our participants were diagnosed with hypertension when utilizing the brachial Blood pressure measurement, when using the central blood pressure data our average participant would be classified as pre-hypertensive. This is confirmed by other research indicating that measures of central blood pressure are significantly lower than brachial measurements (17). These findings further suggest the importance of the inclusion of central blood pressure to better understand overall hemodynamics.

The results from this study indicate that Tai Chi and walking have similar PEH effects in hypertensive individuals. Thus, hypertensive patients will receive similar benefits from participating in either Tai Chi or walking. The presence of PEH supports the recommendation that all hypertensive patients participate in exercise to manage blood pressure through lifestyle modification (7). While PEH in walking has been confirmed in prior research, the PEH response of Tai Chi was unknown, and now has been reported to be similar to the effects of walking. Thus, patients may participate in either exercise to assist in the management of blood pressure.

Another finding of this study is a statistical trend which indicated different changes in heart rate following completion of Tai Chi and walking. Although non-significant, the effect size for the comparisons were .33, and .22, indicating a small effect (Cohen's *d*). This finding may be explained by the impact of Tai Chi on the nervous system. It has been demonstrated in different populations that Tai Chi decreases sympathetic nervous system activity following the activity (19). In combination with activating the parasympathetic nervous system (22) this would result in a reduction in heart rate. This response occurs due to the physiological mechanism associated with vagal tone which occurs due to the meditative effects associated with Tai Chi exercise (24). The increase in vagal tone will result in a decrease in overall sympathetic activity, resulting in a reduction in heart rate.

The lack of change in diastolic blood pressure, both centrally and peripherally was expected because diastolic blood pressure does not change during acute exercise (21). In addition, the lack of change in pulse pressure was not expected due to the significant changes in systolic blood pressure following both activities. The interaction between exercise type and time for central or peripheral systolic blood pressure was not expected. As the trend in heart rate reduction would suggest a directional change in systolic blood pressure but that was not found. Thus, it may be assumed that cardiac output was maintained in both exercise forms through enhanced stroke volume, but this is not confirmed in the results of this study

The strengths of this study include a repeated measures design, control of exercise intensity, and use of the Sphygmacor Excel automated blood pressure device. The repeated measures design allowed each of the subjects to act as their own control, heart rate was controlled in both exercise types to ensure that intensity was similar (approximately 50.2% of age predicted heart rate max), and the automated blood pressure device reduced any bias of the researcher. The weaknesses study were a smaller sample size, lack of diet control, and a lack of randomization of exercise types. Lack of diet control is a concern due to the impacting factor that dietary sodium has on the management of blood pressure. Although there was no randomization of exercise types, Tai Chi was performed first in order to match the heart rate and exercise intensity to walking to ensure an adequate comparison with regard to blood pressure and PEH changes.

In conclusion, both Tai Chi and walking cause reductions in blood pressure following the activity and can be prescribed to hypertensive patients to lower blood pressure. The results from this study verify the existence of PEH in walking, and demonstrate PEH in Tai Chi. In addition, there was a trend indicating Tai Chi may illicit a greater acute reduction in heart rate following the exercise, but future studies need to be conducted to confirm this trend. Both of the exercise types illicit similar PEH effects following exercise. Thus, hypertensive patients can perform either activity to elicit acute reductions in blood pressure that may lead to a more adequately managed blood pressure.

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