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Exercise: An Active Route to Healthy Aging

Tai Chi Chih Acutely Decreases Sympathetic Nervous System Activity in Older Adults

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Background. Aging is associated with increases of sympathetic nervous system activation implicated in the onset of hypertension and cardiovascular disease. The purpose of this study was to examine whether the practice of Tai Chi Chih (TCC), a movement-based relaxation practice, would acutely promote decreases of sympathetic activity in elderly persons.

Method. The sample included two groups of older men and women (age $\geq$ 60 years): TCC practitioners ($n = 19$) and TCC-naïve participants ($n = 13$). Participants were recruited after completing a 25-week randomized trial of TCC or health education. TCC practitioners performed TCC for 20 minutes, and TCC-naïve participants passively rested. Preejection period, blood pressure, and heart rate were measured before and after the task. A subsample ($n = 8$) returned for a second evaluation and performed videotape-guided stretching for 20 minutes to evaluate the effects of slow-moving physical activity on sympathetic activity.

Results. Results showed that TCC performance significantly decreased sympathetic activity as indexed by preejection period ($p = .01$). In contrast, there was no change in preejection period following passive rest or slow-moving physical activity. Neither blood pressure nor heart rate changed after TCC performance.

Discussion. This study is the first to our knowledge to assess the acute effects of TCC practice on sympathetic activity in older adults. TCC performance led to acute decreases in sympathetic activity, which could not be explained by physical activity alone. Further study is needed to determine whether the acute salutary effects of TCC on autonomic functioning are sustained with ongoing practice in older adults.

HUMAN aging is associated with progressive increases in sympathetic nervous system (SNS) activity (1,2), which is implicated in the development of a number of cardiovascular and metabolic conditions including congestive heart failure, atherosclerosis, and hypertension (3,4). Indeed, pharmacologic treatments with beta-adrenergic blocking medication are routinely used for medical management of hypertension and other cardiovascular disorders. However, novel strategies that ameliorate age-related increases of SNS activity are also needed, as such preventative approaches may confer benefits and promote health before hypertension and such medical conditions develop.

Tai Chi, a traditional Chinese form of calisthenics readily exportable to older adults, is reported to have benefits on cardiovascular outcomes (5), although its effects on SNS activity have received little attention (6). Nevertheless, in a randomized clinical trial of postmyocardial infarction patients, 8 weeks of Tai Chi practice led to decreases in resting systolic and diastolic blood pressure (7), and a case–control study by Lan and colleagues (8) reported a greater maximum oxygen consumption (VO_2max) response to the stand and reach test in Tai Chi practioners than in sedentary controls. However, as reviewed by Wang and colleagues, conclusions from these studies are limited by factors such as lack of a control group, use of retrospective designs, and heterogeneous participants. Moreover, comparison of long-time Tai Chi practioners with Tai Chi-naïve controls may be biased by confounding influences of nonspecific person-specific factors (e.g., overall health status, personality factors; 5).

The purpose of this study was to determine whether acute performance of Tai Chi Chih (TCC), a Westernized version of Tai Chi, promotes decreases in SNS activity as measured by preejection period (PEP) in healthy older adults. Passive-rest and physical movement control groups were used to test whether TCC-evoked autonomic effects were present over and above nonspecific effects of laboratory habituation and movement.

Methods

Participants

A total of 32 older adults (aged 60–85 years) participated in the present study, forming two groups: TCC practitioners (9 men, 10 women) and TCC-naïve adults (5 men, 8 women). Participants for this study were recruited from those individuals who had completed the randomized controlled trial ''Behavioral Intervention for Herpes Zoster Risk in Aging'' (ClinicalTrials.gov Identifier: NCT00118885). In this randomized controlled trial, there was a total of 112 participants who were randomly allocated to TCC and health education at two study sites, Los Angeles and San Diego, California. Of the cohort enrolled at the Los Angeles site (n = 72), a total of 63 completed the trial and were eligible to participate in this study; 32 of these completers were enrolled in this study. Participants were recruited after completion of the above-mentioned 25-week trial comparing TCC with health education. The TCC practitioners in the current study were recruited from a group of older adults who had been randomly assigned to the TCC treatment arm of the trial, whereas the TCC-naïve adults were recruited from those persons randomly assigned to the health education treatment arm. All participants in the randomized trial were Tai Chi naïve prior to entry in that study, hence none were self-selected long-term practitioners of TCC. Among the participants who had been allocated to TCC, all reported current practice of TCC at least once per week, having recently completed the prior trial (mean time since completion = 12 weeks) upon entry into the present study. The mean duration of TCC practice was 37 weeks.

The eligibility criteria for the present study were identical to those of the randomized controlled trial that focused on herpes zoster risk or varicella zoster virus immune responses in elderly persons. The eligibility criteria of the randomized controlled trial included a history of varicella or residence in the continental United States for at least 30 years (indicative of prior varicella zoster virus infection) (9,10). Major exclusions were evidence of immunocompromise resulting from disease (e.g., hematologic malignancy, HIV infection), corticosteroids, or other immunosuppressive and/or cytotoxic therapy; prior herpes zoster; receipt of immunizations (e.g., hepatitis B vaccine; influenza vaccine) within 1 month prior to study entry or scheduled over the course of the intervention; any acute current illness that might interfere with interpretation of the study; and the presence of a current major psychiatric disorder as determined by the *Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV) diagnoses (11). Additional trial exclusions were an unwillingness to adhere to study protocol or ongoing participation in any variant of Tai Chi.

To determine whether participants fulfilled the eligibility criteria specified above, a medical and medication history was performed by interview along with screening laboratory tests. All medical history data were reviewed by the principal investigator of the randomized controlled trial (Michael R. Irwin, MD). None of the enrolled participants had histories of cancer (except for local resection of skin cancers), congestive heart failure, or insulin-dependent diabetes mellitus. In addition, persons taking antihypertensive medications or other drugs that might impact sympathetic measures were not eligible for this study. Participants were instructed not to drink caffeinated or alcoholic beverages for at least 24 hours before study participation. This study was approved by the UCLA Institutional Review Board, and all participants provided written informed consent.

Procedures

Participants arrived in the laboratory in the morning between 9:00 AM and 11:00 AM, and their height and weight were recorded. They were asked to sit quietly for 10–15 minutes, after which time they underwent a 10-minute baseline autonomic assessment as described below, which was followed by a 20-minute task period (TCC vs passive rest) and a subsequent posttask 10-minute autonomic assessment. Participants remained seated throughout the autonomic assessments.

TCC is a highly standardized series of 20 prescribed movements. Performance of each of these movements together takes approximately 20 minutes. TCC practitioners were asked to perform TCC for the full duration of the task period. In contrast, TCC-naïve-participants assigned to the passive rest condition watched (while seated) a 20-minute video on the benefits of exercise and nutrition.

Assessment of the Effects of Slow Physical Activity

One mechanism through which TCC may impact PEP is through slow physical activity. Physical movement during aerobic exercise has been shown to affect PEP (12), but it is unclear if slow physical movement can influence PEP. To determine whether slow physical activity could induce changes in autonomic measures, a subsample (n = 8) of participants returned to the laboratory for subsequent autonomic assessment before and after 20 minutes of videotape-guided gentle stretching. This low level of physical activity was similar to TCC in intensity and range of movement. Equal numbers of TCC practitioners (n = 4) and TCC-naïve controls (n = 4) participated in this secondary evaluation. Participants waited at least 1 month after initial autonomic assessment before returning for the slow physical activity portion of the study.

Autonomic Assessment

Autonomic assessment occurred for 10 minutes before and after the task period. Measurements of blood pressure and heart rate were obtained using an automated monitor (Critikon Dinamap 100; GE Medical Systems, Waukesha, WI). The occlusion cuff was fitted to the upper right arm. Blood pressure was measured at minutes 4 and 8 of each 10-minute assessment period. PEP was measured continuously for 10 minutes before and after the task period. PEP, an estimate of SNS-driven myocardial contractility time, was derived via impedance cardiography and electrocardiography by measuring the time in milliseconds from the onset of the Q wave to the onset of left ventricular ejection (i.e., the impedance cardiography B point). PEP is inversely related to SNS activity, such that increases in PEP indicate decreased SNS activity (13,14). For electrocardiography, spot electrodes were attached in a modified Lead II configuration; for impedance cardiography, electrodes were attached using a spot electrode configuration described by Cacioppo and colleagues (15). Electrocardiography and impedance cardiography signals were measured using the HIC-2000 monitor and WIN-COP software (both from BioImpedance Technologies, NC) and subsequently, signals were ensemble averaged into 1-minute samples.

Statistical Analyses

All data were entered and analyzed in SPSS 12.0 (16). Differences between the TCC practitioners versus TCC-naïve participants on continuous demographic variables were tested by analyses of variance (ANOVA). Differences on categorical variables were tested using chi-square tests. For PEP, in which 1-minute samples were recorded across

Table 1. Characteristics and Baseline Blood Pressure of Tai Chi Chih and Passive Rest Participants

Patient Characteristics	Tai Chi Chih Practitioners	Tai Chi Chih Naïve	F	p
Age, y (range)	68 ± 7 (60–85)	69 ± 7 (60–81)	.07	.79
Gender, male/female	9/10	5/8	χ^2 = .25	.62
Body mass index, kg/m^2	24 ± 3	25 ± 5	.08	.77
Ethnicity, Euro-American/ Asian American	16/3	10/3	χ^2 = .24	.61
Education, some college or less/college degree/postgraduate	3/4/12	6/3/3	χ^2 = 5.2	.07
Baseline SBP, mmHg	123 ± 15	125 ± 15	.21	.65
Baseline DBP, mmHg	69 ± 9	72 ± 8	.85	.36
Baseline HR, bpm	61 ± 8	66 ± 8	2.9	.10
Baseline PEP, ms	92 ± 19	91 ± 20	.03	.95

Notes: Values in group columns reflect mean ± standard deviation.

SBP = systolic blood pressure; DBP = diastolic blood pressure; HR = heart rate; PEP = preejection value, latter reflects average of minutes 1–10.

each 10-minute assessment period, a repeated block design was used: 2 (task: TCC, passive rest) × 2 (assessment block: pretask, posttask) × 10 (time: minute of assessment period). A significant Task × Block interaction indicated that task type had different effects on PEP. For blood pressure and heart rate, two readings were done during pretask and two readings were taken posttask; thus a 2 (task: TCC, passive rest) × 4 (assessment: 2 pretask, 2 posttask) repeated-measures ANOVA was used.

Results

Participant Characteristics

Demographic characteristics are presented in Table 1. Both groups were similar in age, gender composition, body mass index, and ethnicity, although there was a trend for TCC practitioners to have a higher proportion of individuals with postgraduate schooling as compared to the TCC-naïve group. The groups did not differ on resting measures of blood pressure, heart rate, and PEP.

Effects of TCC Versus Passive Rest on Autonomic Activity

SNS activity decreased after performance of TCC as evidenced by a significant Task (TCC vs passive rest) × Assessment Block (pretask vs posttask) interaction for PEP, $F(1,28) = 6.83$, $p = .01$. Pretask, both TCC practitioners and TCC-naïve participants had equivalent PEP values (92 ± 19 vs 91 ± 20 ms, respectively; mean ± standard deviation). Posttask, TCC practitioners showed an approximate 5% increase of PEP, whereas PEP did not change following passive rest (97 ± 18 vs 92 ± 23 ms, respectively).

PEP was associated with two demographic variables (age and body mass index) in the total sample (Spearman's $\rho = -.42$; Spearman's $\rho = -.39$, p values $< .05$), but was not related to ethnicity, education, or gender. When age and body mass index were included as covariates in a subsequent repeated measures analysis of covariance (ANCOVA), performance of TCC still produced a significant increase of PEP, $F(1,26) = 6.85$, $p = .02$. Neither blood pressure nor heart rate was different pretask or posttask (p values $> .10$), and there were no significant interactions between task and time for these measures (p values $> .10$).

Effects of Slow Physical Activity on Autonomic Activity

To determine whether slow physical activity might promote changes in PEP, a subsample of participants was asked to return to the laboratory for another autonomic assessment. Gender distribution was equivalent (four men and four women) as was previous exposure to TCC (four practitioners, four TCC-naïve participants). Baseline PEP was 94 ± 26 ms, and post-physical activity PEP was 94 ± 29 ms; repeated-measures ANOVA showed no change in PEP from pre- to postassessment, $F(1, 7) = .002$, $p = .97$. Exploratory analyses were done to determine if TCC practioners and TCC-naïve participants had similar PEP responses following slow physical activity. Mean PEP change from pre- to post- in each group was minimal, <1 ms, and not significant (p values $> .10$). Baseline blood pressure and heart rate were as follows: systolic, 126 ± 12 mmHg; diastolic, 72 ± 7 mmHg; and heart rate, 63 ± 9 bpm. Slow physical activity did not produce significant changes in blood pressure or heart rate (p values $> .10$).

Discussion

This is the first study to demonstrate that the practice of TCC can induce acute decreases of SNS activity as indexed by PEP in healthy older adults. As an estimate of beta-adrenergic driven myocardial contractility, PEP is inversely related to SNS activity, such that *increases* in PEP reflect *decreases* in SNS activity. PEP increased following TCC performance, whereas passive rest did not produce any change in PEP.

The decrease of SNS activity following TCC was similar in magnitude, but inverse in direction, to changes in SNS activity induced by acute stress. For example, TCC practice was associated with a 5% increase of PEP, whereas acute laboratory stress such as evaluative public speaking induces an approximate 5%–7% decrease of PEP in older adults (17–19). Future studies are needed to determine whether the practice of TCC might attenuate stress-induced activation of autonomic arousal mechanisms.

The magnitude of change in PEP that follows TCC is similar to that found following aerobic exercise in older adults; both induce PEP increases of approximately 5 ms (20). Although the clinical implications of such changes in PEP are not fully recognized, there is a substantial literature linking physical exercise with improvements in cardiovascular function (21). Similarly, Tai Chi practice has been shown to improve cardiovascular outcomes such as blood pressure and heart rate (5–8), although these studies have not examined changes in SNS mechanisms.

The study was limited to healthy older adults, and it is not known whether these findings are generalizable to persons who show evidence of marked sympathetic activation and have medical conditions such as hypertension. Changes in SNS activity induced by TCC were not due to variables such as age, body mass index, and health status; gender, ethnicity, and education were not associated with PEP. Studies with larger samples are needed to explore more fully the interrelationships between gender and other demographic variables on TCC and autonomic activity. Furthermore, findings may not generalize to older adult community samples, as participants were enrolled following completion of a randomized controlled evaluation of TCC. Nevertheless, this recruitment strategy ensured that SNS responses following TCC were not due to nonspecific factors related to self-selection for TCC or long-term practice. Another limitation of this study was the duration of the PEP assessment period, with measures taken for 10 minutes before and for 10 minutes after Tai Chi practice. It is not known whether decreases of sympathetic activity following TCC extend beyond the 10-minute assessment period, although Lu and Kuo (6) reported in an uncontrolled study that decreases in sympathovagal balance persisted for 30 and 60 minutes after Tai Chi performance. Finally, habituation to the laboratory assessment environment does not explain these effects of TCC, as PEP did not change in either the passive rest or physical activity control conditions.

Tai Chi has been described as ''meditation through movement'' and can be characterized as consisting of a series of prescribed slow, purposeful movements with an emphasis on concentration and relaxation. Besides behavioral and self-report measures, few studies have carefully examined physiological pathways affected by Tai Chi. Our findings support the hypothesis that TCC promotes decreased SNS activity, although changes in blood pressure or heart rate were not found, possibly due to short duration of TCC practice assessment. The mechanisms accounting for the changes in PEP are unclear. Subsample analyses that explored the effects of slow physical movement indicated that such activity is not sufficient to alter PEP. We speculate that TCC may alter sympathetic activity in the short term via other mechanisms such as relaxation and/or meditation.

The SNS is an extensive network of peripheral nerves that play a major role in modulating cardiovascular and metabolic functions both tonically as well as in response to changing environmental demands. Increases in tonic activity of the SNS are associated with a number of diseases, such as hypertension, congestive heart failure, and diabetes (22), and sympathetic tone increases with age (4). Treatment with medications that buffer the effects of the SNS on systemic physiology, such as beta-adrenergic receptor blockade, has beneficial effects on cardiovascular disease risk. It is not known whether behavioral strategies (such as TCC) that acutely attenuate sympathetic arousal mechanisms will have similar salutary effects on cardiovascular or other health outcomes in older adults.

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