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## Variability in resting heart rate in older women practicing Tai Chi Chuan versus non-exercising controls: a cross-sectional comparative study

Variabilidad de la frecuencia cardíaca en reposo en mujeres mayores que practican taichí chuan frente a controles no practicantes de ejercicio: un estudio comparativo transversal

Variabilidade da frequência cardíaca em repouso em mulheres idosas praticantes de Tai Chi Chuan em comparação com controles que não praticam exercícios: um estudo comparativo transversal

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### ABSTRACT

**PURPOSE:** The study compared Resting Heart Rate Variability (HRV) in elderly women practicing Tai Chi Chuan (TCC) versus non-exercising controls to evaluate its impact on heart autonomic modulation. **METHODOLOGY:** Twenty elderly women were allocated into two groups: TCC practitioners (n=10) and non-exercising controls (n=10). The groups were similar in baseline characteristics, including age (TCC: 64.6 ± 3.3 yrs; control: 66.5 ± 7.3 yrs), body mass (TCC: 60.8 ± 4.3 kg; control: 65.5 ± 12.1 kg), height (TCC: 1.52 ± 0.07 m; control: 1.50 ± 0.05 m), and BMI (TCC: 26.2 ± 2.7 kg/m<sup>2</sup>; control: 28.9 ± 4.3 kg/m<sup>2</sup>). HRV was assessed using a heart rate monitor and symbolic analysis, focusing on 0V% (sympathetic activity) and 2ULV% (parasympathetic activity). **RESULTS:** For sympathetic modulation (0V%), the TCC group exhibited significantly lower values at moment 1 (TCC: 28.7 ± 7.9 vs. control: 41.6 ± 8.6, p = 0.003, 95%CI: -20.74 to -5.07; d = -1.56) and moment 2 (TCC: 27.0 ± 12.0 vs. control: 38.9 ± 11.7, p = 0.038, 95%CI: -23.09 to -0.72; d = -1.00), indicating reduced sympathetic dominance among TCC practitioners. In contrast, parasympathetic modulation (2ULV%) was significantly higher in the TCC group at moment 1 (TCC: 13.9 ± 3.5 vs. control: 10.6 ± 2.5, p = 0.032, 95%CI: 0.31 to 6.17; d = 1.08) and moment 2 (TCC: 14.4 ± 3.5 vs. control: 10.5 ± 3.3, p = 0.021, 95%CI: 0.67 to 7.21; d = 1.15). **CONCLUSION:** The findings highlight the benefits of regular TCC practice, demonstrating its potential to enhance parasympathetic activity and reduce sympathetic activity, thus contributing to autonomic balance and possible cardiovascular protection. Despite limitations like the small sample size and cross-sectional design, TCC is identified as a promising non-pharmacological intervention for cardiovascular

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health improvement in elderly women, with symbolic analysis effectively capturing patterns of autonomic regulation.

**KEYWORDS:** physical activity, elderly people, health, tai chi chuan.

## RESUMEN

**OBJETIVO:** El estudio comparó la variabilidad de la frecuencia cardíaca en reposo (VFC) entre mujeres mayores que practicaban taichí chuan (en adelante TCC) y controles no practicantes de ejercicio, con el objetivo de evaluar su impacto en la modulación autonómica cardíaca. **METODOLOGÍA:** Veinte mujeres mayores fueron asignadas a dos grupos: practicantes de TCC ( $n = 10$ ) y controles no practicantes de ejercicio ( $n = 10$ ). Los grupos fueron similares en sus características basales, incluyendo edad (TCC:  $64.6 \pm 3.3$  años; control:  $66.5 \pm 7.3$  años), masa corporal (TCC:  $60.8 \pm 4.3$  kg; control:  $65.5 \pm 12.1$  kg) y estatura (TCC:  $1.52 \pm 0.07$  m; control:  $1.50 \pm 0.05$  m) e IMC (TCC:  $26.2 \pm 2.7$  kg/m<sup>2</sup>; control:  $28.9 \pm 4.3$  kg/m<sup>2</sup>). La VFC fue evaluada mediante un monitor de frecuencia cardíaca y análisis simbólico, con énfasis en los índices 0V% (actividad simpática) y 2ULV% (actividad parasimpática). **RESULTS:** Para la modulación simpática (0V%), el grupo TCC presentó valores significativamente menores en el momento 1 (TCC:  $28.7 \pm 7.9$  vs. control:  $41.6 \pm 8.6$ ,  $p = .003$ , 95%CI: -20.74 a -5.07;  $d = -1.56$ ) y en el momento 2 (TCC:  $27.0 \pm 12.0$  vs. control:  $38.9 \pm 11.7$ ,  $p = .038$ , 95%CI: -23.09 to -0.72;  $d = -1.00$ ), lo que indica una menor dominancia simpática entre las practicantes de TCC. En contraste, la modulación parasimpática (2ULV%) fue significativamente mayor en el grupo TCC tanto en el momento 1 (TCC:  $13.9 \pm 3.5$  vs. control:  $10.6 \pm 2.5$ ,  $p = .032$ , 95%CI: 0.31 a 6.17;  $d = 1.08$ ) como en el momento 2 (TCC:  $14.4 \pm 3.5$  vs. control:  $10.5 \pm 3.3$ ,  $p = .021$ , 95%CI: 0.67 a 7.21;  $d = 1.15$ ). **CONCLUSIÓN:** Los hallazgos destacan los beneficios de la práctica regular de TCC, demostrando su potencial para aumentar la actividad parasimpática y reducir la simpática, lo que contribuye al equilibrio autonómico y a una posible protección cardiovascular. A pesar de limitaciones como el tamaño reducido de la muestra y el diseño transversal, el TCC se identifica como una intervención no farmacológica prometedora para la mejora de la salud cardiovascular en mujeres adultas mayores, siendo el análisis simbólico una herramienta eficaz para captar los patrones de regulación autonómica.

**PALABRAS CLAVE:** actividad física, personas adultas, salud, tai chi chuan.

## RESUMO

**OBJETIVO:** O estudo comparou a variabilidade da frequência cardíaca em repouso (VFC) entre mulheres idosas que praticavam Tai Chi Chuan (doravante TCC) e mulheres do grupo de controle que não praticavam exercícios, com o objetivo de avaliar seu impacto na modulação autonômica cardíaca. **METODOLOGIA:** Vinte mulheres idosas foram divididas em dois grupos: praticantes de TCC ( $n = 10$ ) e grupo controle que não praticam exercícios ( $n = 10$ ). Os grupos apresentaram características basais semelhantes, incluindo a idade (TCC:  $64,6 \pm 3,3$  anos; grupo de controle:  $66,5 \pm 7,3$  anos), massa corporal (TCC:  $60,8 \pm 4,3$  kg; grupo de controle:  $65,5 \pm 12,1$  kg) e altura (TCC:  $1,52 \pm 0,07$  m; grupo de controle:  $1,50 \pm 0,05$  m) e IMC (TCC:  $26,2 \pm 2,7$  kg/m<sup>2</sup>; grupo de controle:  $28,9 \pm 4,3$  kg/m<sup>2</sup>). A VFC foi avaliada por meio de um monitor de frequência cardíaca e análise simbólica, com ênfase nos índices

0V% (atividade simpática) e 2ULV% (atividade parassimpática). **RESULTADOS:** Para a modulação simpática (0% V), o grupo TCC apresentou valores significativamente mais baixos no momento 1 (TCC:  $28,7 \pm 7,9$  em comparação com o grupo de controle:  $41,6 \pm 8,6$ ,  $p = 0,003$ , 95%CI: -20,74 a -5,07;  $d = -1,56$ ) e no momento 2 (TCC:  $27,0 \pm 12,0$  em comparação com o grupo de controle:  $38,9 \pm 11,7$ ,  $p = 0,038$ , 95%CI: -23,09 a -0,72;  $d = -1,00$ ), o que indica uma menor dominância simpática entre as praticantes de TCC. Em contrapartida, a modulação parassimpática (2ULV%) foi significativamente maior no grupo TCC tanto no momento 1 (TCC:  $13,9 \pm 3,5$  em comparação com o grupo de controle:  $10,6 \pm 2,5$ ,  $p = 0,032$ , 95%CI: 0,31 a 6,17;  $d = 1,08$ ) e no momento 2 (TCC:  $14,4 \pm 3,5$  em comparação com o grupo de controle:  $10,5 \pm 3,3$ ,  $p = 0,021$ , 95%CI: 0,67 a 7,21;  $d = 1,15$ ). **CONCLUSÃO:** Os resultados destacam os benefícios da prática regular da TCC, demonstrando seu potencial para aumentar a atividade parassimpática e reduzir a simpática, o que contribui para o equilíbrio autonômico e para uma possível proteção cardiovascular. Apesar de limitações como o tamanho reduzido da amostra e o desenho transversal, o TCC se destaca como uma intervenção não farmacológica promissora para a melhoria da saúde cardiovascular em mulheres idosas, sendo a análise simbólica uma ferramenta eficaz para identificar os padrões de regulação autonômica.

**PALAVRAS-CHAVE:** atividade física, pessoas idosas, saúde, Tai Chi Chuan.

## 1. Introduction

In recent years, studies have focused on the Autonomic Nervous System (ANS) and its role in health and disease, investigating the potential benefits and risks associated with the function and dysfunction of its branches, the sympathetic and parasympathetic systems (Cancino, [2011](#); Thayer et al., [2012](#); Young & Benton, [2018](#)). Previous research has demonstrated that the modulation of Heart Rate Variability (HRV) is influenced by certain physiological factors, such as aging (Hayano & Yuda, [2019](#); Singh et al., [2018](#)), body fat (Yadav et al., [2017](#)), and aerobic condition (Kaufmann et al., [2023](#)). However, the primary interest in evaluating vagal cardiac activity lies in its prognostic value for cardiovascular risk, as it has been shown to exert a cardioprotective effect through improved cardiac electrical stability (Billman, [2013](#); Francesco Sessa et al., [2018](#)).

HRV has been used to assess cardiac function, where low parasympathetic activity is a predictor of cardiovascular complications (Fang et al., [2020](#); Hillebrand et al., [2013](#)). Evaluating HRV at rest, during, and after exercise is an innovative approach to study the different underlying physiological control mechanisms of the body that respond to physical activity (Michael et al., [2017](#); Stanley et al., [2013](#)). The greater the temporal variability of the intervals between consecutive beats, the higher the parasympathetic activity (Laborde et al., [2017](#); Shaffer & Ginsberg, [2017](#)). In this short period between beats, Heart Rate (HR) is controlled by both sympathetic and parasympathetic activity, with HR fluctuations serving as a way to observe the integrity of the ANS (Cambri et al., [2008](#)).

Moreover, the relationship between physical activity, health, quality of life, and aging has been increasingly discussed and analyzed scientifically. It is practically a consensus among health professionals that physical activity is a determining factor in the success of the aging process (Rebello-Marques et al., [2018](#)).

Considering the practice of physical activity, Tai Chi Chuan (TCC) can improve aerobic capacity when practiced long-term (Tan et al., [2022](#)). It also influences the endogenous neuro-hormonal feedback mechanism by increasing HRV and reducing sympathetic activity (Bellenger et al., [2016](#)), suggesting an accumulated effect of physical training on autonomic balance (Rogers et al., [2021](#)). Additionally, physical inactivity is an important risk factor for cardiovascular disease (Ekelund et al., [2019](#)), and in the elderly, autonomic control tends to be altered with a reduction in parasympathetic activity and an increase in sympathetic activity, which has important clinical implications (Arantes et al., [2022](#); Monahan, [2007](#)). Therefore, considering that TCC can improve aerobic capacity (Tan et al., [2022](#)) as well as influence HRV (Xia, [2023](#)), the purpose of this study was to compare the resting heart rate variability between elderly women practicing TCC and non-exercising controls.

## 2. Methods

### Experimental Design

The study followed a cross-sectional comparative design. Each group attended two assessment sessions scheduled one week apart. The first visit served as a familiarization session (i.e., Moment 1), during which participants were introduced to all evaluation procedures to reduce potential learning or adaptation effects. The second visit corresponded to the official assessment used for analysis (i.e., Moment 2). All evaluations were performed at the same time of day (07:00-09:00) to minimize circadian influences on physiological measures.

As part of the inclusion and exclusion criteria, participants could not have cardiovascular diseases, could not be smokers, and were not allowed to use calcium channel blockers or other medications known to affect autonomic function, including beta-blockers. Therefore, individuals using these substances were not eligible to participate in either group (TCC practitioners or non-practitioners).

To further standardize physiological conditions, participants were instructed to abstain from consuming coffee, caffeinated beverages, energy drinks, alcohol, or any other stimulants for at least 24 hours prior to each assessment. They were also advised to avoid structured physical activity or prolonged exercise throughout the study period, except for routine daily activities. These procedures ensured that study period, except for routine daily activities. To ensure adherence to this recommendation, participants received written and verbal instructions before each assessment session and were asked to confirm compliance upon arrival for both visits. Additionally, any indication of non-compliance (e.g., reports of recent exercise, unusual fatigue, or musculoskeletal discomfort) would lead to rescheduling the evaluation. These procedures allowed us to verify that no additional physical activities were performed outside of daily routines. These procedures ensured that both groups were assessed under comparable and controlled conditions.

### Participants

The sample consisted of 20 elderly women who were divided into two groups: elderly women practicing TCC (n=10), with a practice duration of at least 6 months and no more than 1 year, and practiced only TCC; and a group of non-exercising controls (n=10). The sample

characteristics are presented in [Table 1](#). There were no statistically significant differences between groups for any of the variables analyzed ( $p>0.05$ ).

The elderly women in the TCC group regularly practiced the Wu style three times per week under the supervision of a certified instructor with more than five years of experience in this modality. Each training session lasted 50 minutes and followed a standardized structure: 10 minutes of warm-up, 35 minutes of specific Wu-style practice, and 5 minutes of cool-down.

The warm-up consisted of low-intensity mobility exercises and stretching targeting major muscle groups of both the upper and lower limbs, as well as proprioceptive and balance drills performed in a standing position. The main TCC segment involved approximately 80 Wu-style postures performed in a continuous, coordinated sequence (e.g., Opening Posture [Qi Shi]; Parting the Wild Horse's Mane [Ye Ma Fen Zong]). Selected postures were repeated throughout the sequence to reinforce motor learning and ensure consistency of technique. All training sessions were performed in small groups (5-10 participants) in a controlled indoor environment, ensuring uniformity of practice conditions. The 5-minute cool-down period consisted of slow breathing exercises, gentle range-of-motion activities, and brief static stretching performed in a relaxed stance (e.g., arm-floating relaxation movements; gentle neck). These procedures aimed to promote physiological recovery, gradually reduce heart rate, and facilitate the transition to resting conditions.

Table 1.

*Sample Characterization. Data expressed as mean and ( $\pm$ ) standard deviation.*

	<b>TCC (n=10)</b>	<b>Non-exercising controls (n=10)</b>	<b>p</b>
<b>Age (years)</b>	64,6 ( $\pm 3,3$ )	66,5 ( $\pm 7,3$ )	0,467
<b>Body mass (kg)</b>	60,8 ( $\pm 4,3$ )	65,5 ( $\pm 12,1$ )	0,268
<b>Height (m)</b>	1,52 ( $\pm 0,07$ )	1,50 ( $\pm 0,05$ )	0,430
<b>BMI (kg.m<sup>-2</sup>)</b>	26,2 ( $\pm 2,7$ )	28,9 ( $\pm 4,3$ )	0,117

TCC – group of elderly women practicing Tai Chi Chuan; BMI – Body Mass Index. Source: the authors.

As inclusion criteria, participants could not have cardiovascular diseases, use calcium channel blockers, or be smokers. All subjects were informed about the procedures, potential benefits, and risks associated with the study, and their participation was conditioned on voluntary consent through the signing of a free and informed consent form. The research protocol was designed in accordance with the ethical principles outlined in the Helsinki Declaration and the guidelines proposed in Resolution 466/2012 of the National Health Council of Brazil regarding research involving human subjects. It was approved by the Ethics and Research Committee of the Federal University of Rio Grande do Norte (UFRN) under protocol no. 340/2011-CEP/HUOL.

## Measures

### Anthropometric Assessment Description

Weight and height were measured during the first assessment session, prior to any other testing procedures. Body weight was obtained using a calibrated digital scale (Pienna® MEA-03150, São Paulo, Brazil) with a precision of 0.1 kg, with participants wearing light clothing and no shoes. Height was measured using a wall-mounted stadiometer (Sanny® Standard

ES-2030. São Bernardo do Campo, Brazil) with a precision of 0.1 cm, following standardized anthropometric procedures. All measurements were collected by the same trained evaluator to ensure methodological consistency. These values were subsequently used to calculate Body Mass Index (BMI).

### Symbolic Analyss Procedure (Heart Rate Variability)

A heart rate monitor (Polar® RS800CX) was used to record beat-to-beat heart rate, monitored every 5 seconds during rest. Participants were kept in the supine position for 10 minutes to analyze HRV at rest. To reduce the influence of external and internal factors, data collection was carried out in a quiet environment with a comfortable temperature (approximately 22-24 °C), where volunteers were encouraged to remain awake and mentally relaxed throughout the collection.

The HRV collection protocol used was based on the recommendations of the Task Force (American Heart Association, [1996](#)). For HRV analysis, we used symbolic analysis (Guzzetti et al., [2005](#)). Non-stationary signals reduce HRV patterns, directly affecting symbolic indices, and may suggest a greater contribution of sympathetic control influencing cardiovascular mechanisms and reducing cardiovascular regulation complexity. Therefore, experimental protocols have been developed to keep external influences under control and ensure careful supervision of the experimental environment (Magagnin et al., [2011](#)). However, short-term HRV recordings are conventionally considered stationary, provided that experimental settings are carefully controlled to minimize external influences on symbolic indices (Porta et al., [2004](#)).

RR interval records (i-RR) were manually edited through visual inspection to remove outliers. However, assessing stationarity through visual inspection may be inadequate (Porta et al., [2004](#)). Therefore, we adopted a double-blind approach for selecting the segments. Subsequently, the records were automatically filtered using Polar Precision Performance software (version 3.02.007). For symbolic analysis, we used the protocol suggested by Porta et al. ([2001](#)). The symbolic analysis was performed using the SA software (Symbolic Analysis, Department of Preclinical Sciences, University of Milan, Italy).

### Symbolic analysis: methodological details

Symbolic analysis was conducted to explore the short-term non-linear dynamics of heart rate variability and identify sympathetic and parasympathetic modulations. First, each RR intervals (i-RR) series was transformed into a sequence of discrete symbols according to its amplitude distribution, divided into six quantization levels (0 to 5). From this symbolic series, patterns of three consecutive symbols (triads) were constructed and categorized into four distinct families, based on the number and type of variations between consecutive symbols (Guzzetti et al., [2005](#); Porta et al., [2007](#)).

- 0V patterns: all three symbols are identical (e.g., 2-2-2), indicating no variation between consecutive heartbeats. These patterns are primarily associated with sympathetic modulation.
- 1V patterns: two consecutive symbols are equal and one is different (e.g., 3-3-1), representing a single variation.
- 2LV patterns: two consecutive variations occur in the same direction (e.g., 1-3-5 or 5-3-1), representing monotonic sequences.

- 2ULV patterns: two consecutive variations occur in opposite directions (e.g., 3-5-2 or 4-2-3), forming peaks or valleys, which are mainly associated with parasympathetic modulation.

For each subject, the percentage of occurrence of each pattern type was calculated over the total number of triads, expressed as 0V%, 1V%, 2LV%, and 2ULV%. According to Takahashi et al. (2012), 0V% reflects sympathetic predominance, whereas 2ULV% indicates parasympathetic modulation and greater autonomic complexity.

Short-term HRV segments were considered stationary, as the experimental environment was controlled to minimize external disturbances. The symbolic indices derived from this analysis (0V% and 2ULV%) were used for subsequent statistical comparisons between conditions.

### Statistical Analysis

Data distribution was assessed using the Shapiro-Wilk test to verify normality assumptions. Between-group comparisons were performed using Student's t-test for independent samples. Descriptive statistics are reported as mean and standard deviation.

Given the limited prior data on effect sizes of symbolic HRV indices in elderly Tai Chi practitioners, formal a-priori sample-size estimation was not performed. We based this exploratory study on methodological recommendations for pilot studies and on reliability metrics reported in the literature (Gąsior et al., 2022; Julious, 2005), and we report effect sizes to inform future confirmatory studies. The sample was therefore based on feasibility and accessibility within the target population, and the analyses aimed to generate preliminary evidence to inform future confirmatory studies.

All statistical tests were two-tailed, and a significance level of  $p \leq 0.05$  was adopted. Since only one planned comparison between the two groups was conducted, no post-hoc procedures were required. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) for Windows, version 19.0 (SPSS Inc., Chicago, IL, USA).

## 3. Results

The elderly women practicing TCC have significantly better ( $p \leq 0.05$ ) autonomic modulation at rest in both instances when compared to non-exercising controls, considering HRV markers for sympathetic (0V%) and parasympathetic (2ULV%) modulation (Table 2) (Camilo Pereira et al., 2026).

Table 2.

Comparison of resting heart rate variability between elderly women practicing Tai Chi Chuan (TCC) (n=10) and non-exercising controls (n=10). Data are expressed as mean and ( $\pm$ ) standard deviation.

	Moment 1			Moment 2		
	TCC	Non-exercising controls	<i>p</i>	TCC	Non-exercising controls	<i>p</i>
<b>0V%</b>	28.7 ( $\pm$ 7.9)	41.6 ( $\pm$ 8.6)	0.003	27.0 ( $\pm$ 12.0)	38.9 ( $\pm$ 11.7)	0.038
<b>2ULV%</b>	13.9 ( $\pm$ 3.5)	10.6 ( $\pm$ 2.5)	0.032	14.4 ( $\pm$ 3.5)	10.5 ( $\pm$ 3.3)	0.021

TCC – Tai Chi Chuan practitioners group; 0V% – Sympathetic domain; 2ULV% – Parasympathetic domain. Source: the authors.

Regarding sympathetic modulation, as indicated by 0V%, the TCC group exhibited significantly lower values at Moment 1 (TCC: 28.7  $\pm$  7.9, vs. control: 41.6  $\pm$  8.6, *p* = 0.003, 95%CI: -20.74 to -5.07; *d* = -1.56) and Moment 2 (TCC: 27.0  $\pm$  12.0 vs. control: 38.9  $\pm$  11.7, *p* = 0.038, 95%CI: -23.09 to -0.72; *d* = -1.00), reflecting reduced sympathetic dominance among TCC practitioners.

In contrast, parasympathetic modulation assessed through 2ULV% was significantly higher in the TCC group at both assessments, Moment 1 (TCC: 13.9  $\pm$  3.5 vs. control: 10.6  $\pm$  2.5, *p* = 0.032, 95%CI: 0.31 to 6.17; *d* = 1.08) and Moment 2 (TCC: 14.4  $\pm$  3.5 vs. control: 10.5  $\pm$  3.3, *p* = 0.021, 95%CI: 0.67 to 7.21; *d* = 1.15), demonstrating enhanced parasympathetic influence.

Collectively, these findings indicate that, across both sessions, elderly women engaged in TCC consistently showed lower sympathetic activation and greater parasympathetic modulation, supporting a more balanced autonomic regulation at rest when compared with their non-exercising counterparts. These analyses were supported by the normal distribution of the data (Shapiro-Wilk, *p* = 0.086).

#### 4. Discussion and conclusion

Our results indicate that older women who have been practicing TCC for at least six months and no more than one year, engaging solely in TCC training three times a week showed better autonomic nervous system behavior, as reflected by HRV parameters, compared to their non-exercising counterparts. This finding aligns with a growing body of evidence suggesting the positive impact of TCC on various health markers in older populations.

Previous research has extensively documented that TCC can improve overall health outcomes (Lan et al., 2013), enhance functional capacity (Chen et al., 2024; Xianjian & Datao, 2021), and specifically boost aerobic capacity in the elderly (Tan et al., 2022; Zheng et al., 2015). Considering that robust aerobic capacity is closely associated with favorable vagal modulation and higher HRV (Michael et al., 2017; Schüttler et al., 2020), it is plausible that the

TCC training undertaken by the participants in our study contributed significantly to the observed differences in autonomic function. Indeed, aerobic training, in general, is known to improve HRV by beneficially altering neuroregulatory control over the heart (Bellenger et al., 2016). More specifically, TCC practice has been demonstrated to enhance HRV, often characterized by a reduction in sympathetic activity and/or an increase in parasympathetic influence in both younger and older individuals (Blake & Hawley, 2012; Larkey et al., 2024). This autonomic shift may be partly mediated by an improvement in baroreflex sensitivity, a common adaptation to regular physical activity that contributes to better cardiovascular health (Monahan, 2007; Soares-Miranda et al., 2014). Consequently, HRV stands as an effective and non-invasive tool to assess cardiovascular and autonomic adaptations to interventions like TCC (Shaffer & Ginsberg, 2017).

Another crucial factor that likely influenced our findings is the inherent nature of TCC. It is recognized as a mind-body practice that emphasizes the harmonious balance of body and mind through a unique combination of focused meditation, slow, deliberate, and gentle movements, deep diaphragmatic breathing, and profound full-body relaxation (Lan et al., 2013; Larkey et al., 2024). Given that respiratory patterns, particularly the rate and depth of breathing, directly modulate HRV through Respiratory Sinus Arrhythmia (RSA), a mechanism by which heart rate increases during inhalation and decreases during exhalation due to vagal modulation, RSA reflects the phasic influence of the vagus nerve on the sinoatrial node. During inhalation, vagal efferent activity is transiently inhibited, allowing heart rate to accelerate, whereas during exhalation, vagal activity is restored or enhanced, producing cardiac deceleration (Laborde et al., 2017; Shaffer & Ginsberg, 2017), we believe that the dedicated practice of TCC, with its integral breathing techniques, may have substantially contributed to the enhanced vagal modulation observed in our TCC group. This is supported by studies indicating that TCC can indeed alter vagal tone through its specific breathing patterns and mindful execution (Lu & Kuo, 2003; Zou et al., 2018). Moreover, it has been demonstrated that even relatively short-term engagement with TCC can promote favorable shifts in vagal modulation and sympathovagal balance, often by reducing sympathetic drive, particularly in older adult populations (Blake & Hawley, 2012; Lu & Kuo, 2003 for longer-term but relevant to elderly women).

Despite the relevant contributions of this study, some limitations must be acknowledged. The small sample size (i.e., 20) reduces statistical power and limits the generalizability of the findings to the broader population of elderly women. Nevertheless, the application of rigorous inclusion criteria and the homogeneity between groups, evidenced by the absence of significant differences in the sample characteristics, help reduce sample variability and strengthen the internal validity of the results. The short duration of TCC (i.e., minimum of 6 months and maximum of 1 year) restricts the understanding of the long-term effects of this modality on HRV. However, this period of practice proved sufficient to detect significant differences in autonomic modulation between practitioners and non-exercising individuals, suggesting that even a relatively short duration of practice may provide measurable benefits. Although external variables were controlled during HRV assessments (e.g., time of day and environmental conditions), individual lifestyle factors such as diet, stress levels, sleep quality, and unreported physical activities were not systematically controlled and may have influenced the outcomes. Nevertheless, participants were instructed to maintain their usual routines and refrain from engaging in additional physical activities during the study, which helped minimize these potential biases. The inclusion of women only limits the extrapolation of the findings to

elderly men; on the other hand, it increases sample uniformity by avoiding the potential influence of sex-related differences in autonomic modulation. Additionally, the cross-sectional design does not allow for the establishment of cause-and-effect relationships between the practice of TCC and modulation of the autonomic nervous system. However, the controlled experimental procedures and the comparison between groups with similar characteristics lend robustness to the associations observed.

This study presents important strengths. First, it is a carefully controlled investigation, with standardized data collection procedures conducted at the same time of day and in a controlled environment, thereby minimizing potential external interferences. The use of symbolic analysis as a tool for assessing HRV represents a notable methodological distinction, as it enables the detection of complex aspects of autonomic modulation that are not captured by traditional linear methods. In addition, the sample was carefully selected, with rigorous inclusion criteria that ensured homogeneity between groups and minimized potential confounding factors, such as cardiovascular diseases and the use of medications that influence HRV. Finally, this investigation contributes to the literature by exploring the effects of the Wu Style of TCC, the second most popular branch, originating from Wu Quanyou, a disciple of Yang Luchan, and later refined by Wu Jianquan. Unlike the Yang style, which emphasizes large, open, and expansive movements, or the Chen style, which incorporates pronounced spiraling force, explosive power (*fa jin*), and lower stances, the Wu style is defined by its small-frame technique, compact postures, reduced amplitude of motion, and an upright, narrow-foot stance. This structural configuration results in smoother weight transitions, minimized muscular tension, and a more continuous flow with subtle joint mobilization, characteristics that may promote a more stable respiratory pattern and reduced sympathetic activation. Furthermore, compared with the Sun style, which integrates higher steps and more pronounced stepping transitions, the Wu style favors soft, sustained movements and greater emphasis on relaxation of the upper body, facilitating conditions that are conducive to enhanced vagal modulation. Given these distinctive biomechanical and energetic features, the Wu style may elicit lower postural demand, reduced isometric tension, and greater respiratory regularity, all of which are mechanisms linked to improvements in autonomic regulation. Therefore, examining this less-studied modality provides valuable insight into how different Tai Chi styles may differentially influence autonomic outcomes, offering additional evidence regarding the benefits of mind-body practices for cardiovascular health in elderly women.

Elderly women engaging in regular TCC practice demonstrated superior autonomic modulation at rest compared to their non-exercising counterparts, as evidenced by favorable shifts in HRV markers-specifically, lower sympathetic (0V%) and higher parasympathetic (2ULV%) indices. These findings suggest that TCC may exert a positive influence on cardiac autonomic balance, potentially conferring cardiovascular protection in this population. Symbolic analysis of HRV thus underscores the relevance of TCC as a non-pharmacological strategy for promoting autonomic health in elderly women. Further longitudinal and randomized intervention-based studies are warranted to elucidate the mechanisms underlying these effects, to verify their causal pathways, and to determine their long-term clinical implications.

**Contributions:** Lucas Camilo Pereira (A-C-D), Júlio Cesar Barbosa de Lima Pinto (B-C-E), Renê de Caldas Honorato (B-D-E), Hassan Mohamed Elsangedy (C-D-E), André Igor Fonteles (A-C-E)

**A**-Financing, **B**-Study design, **C**-Data collection, **D**-Statistical analysis and interpretation of results, **E**-Manuscript preparation

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