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Effects of Tai Chi exercise on heart rate variability

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ABSTRACT

Tai Chi is a callisthenic exercise form that incorporates aerobic exercise with diaphragmatic breathing. These two aspects alone have been shown to enhance the heart rate variability, warranting research into the effects of Tai Chi on autonomic nervous system modulation and heart rate variability. A low heart rate variability has been shown to be indicative of compromised health. Any methods to enhance the heart rate variability, in particular, non-pharmacological methods, are therefore seen as beneficial to health and are sought after. The aim of this review was to comprehensively summarize the currently published studies regarding the effects of Tai Chi on heart rate variability. Both consistent and inconsistent findings are presented and discussed, and an overall conclusion attained which could benefit future clinical studies.

1. Introduction

Tai Chi (TC), also termed Tai Chi Chuan (TCC) [1] is a callisthenic exercise form, originating from China over 400 years ago [2–5]. It is a moderate [6] aerobic exercise form [7,8], which elicits a meditative effect [9,10], and incorporates slow [3] and deep breathing [1,2,11], with mental concentration [1,3,4,7] and slow [2–4,7,12], gentle circular movements [3,7]. The upper body moves whilst the lower body is kept in a semi squat position [2,3]. The movements called 'postures' are performed continuously one after the other to produce a "form" [2,3,7,12]. There are various styles of TC, namely Yang, Sun, Chen, and Wu [5]. Other forms/modifications include Taijiquan/Taichiquan (TCQ), and Tai Chi Chih (TCCh) [1]. The styles of TC can be modified to alter the number of postures to make the form easier to learn and perform [2,13]. The postures can also be altered to make them safer to perform [13]. Likewise, the postures can be modified, or certain postures selected in order to improve specific aspects of participants' fitness [2,13]. TC can therefore be made suitable for any age and health status. Hence, TC has been shown to be safe for not only patients with good health, but also those with prolonged illnesses [2,5].

TC is becoming increasingly popular worldwide, given its numerous health benefits [2,3]. It has been shown that TC has the ability to improve symptoms of several types of cancer [14], Parkinson's and cognitive impairment [15], reduce anxiety [16] and stress [15,17], enhance balance [17–19], augment flexibility [20], increase strength [17,18,20], improve cardiovascular risk factors, increase aerobic capacity [18], improve symptoms ensuing rheumatologic diseases [17], and reduce blood pressure [16]. Additional benefits of TC include its ability to be practised individually at home or as part of a group [2,12] since it can either incorporate exercise into busy lifestyles, or facilitate socialising [2]. Moreover, TC can be performed anywhere, does not require any equipment [2,12,21], is a cheap form of exercise [2,21], and is suitable for all [12] due to its ability to be adapted.

One of several objective measures to determine the effectiveness of TC includes its possible ability to alter the cardiac autonomic control, known as the heart rate variability (HRV). HRV is the variation in the period between consecutive R–R intervals on an electrocardiogram (ECG) [22]. HRV parameters can be used to infer the cardiac sympatho-vagal balance in our body, and the degree of parasympathetic to sympathetic modulation [23]. Although there are various markers of autonomic modulation [22,23], HRV is

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considered a superior option due to its low cost [23] and ease to record [22] since it can be measured automatically [22] and non-invasively [23].

Problems in cardiac autonomic modulation can be identified by a depressed HRV [24,25]. This decrease in the variation in beat-to-beat intervals is due to an imbalance in sympathetic to vagal modulation, more specifically, a deficiency in the parasympathetic influence [26], and markedly enhanced sympathetic activity [22,27]. Depressed HRV offers prognostic significance in a number of different circumstances. It can be used as a prognostic indicator following acute myocardial infarction [28–30], coronary heart disease (CHD) [24,31] and heart failure [24,32]. A depressed HRV can also have prognostic implications in the general population, and may be representative of poor health [27,33]. Any methods to increase HRV are therefore considered beneficial to health and are sought after. Slow and deep breathing [34–36] and aerobic exercise are two methods shown to enhance vagal modulation [37,38] and therefore increase the HRV. Since TC famously incorporates aerobic exercise [7,8] with "diaphragmatic breathing" [11], this justifies the assumption that TC has the possibility to enhance HRV [11].

It has been shown that the elderly [39–41] and those suffering with a cardiovascular disorder (CVD) are two major groups who often display depressed HRV [24,26]. Exercise is essential and integral in these populations, and it is particularly important for any exercise methods these patients attempt to be safe. TC could be a chosen exercise form [12], since it is suitable for participants who cannot cope with average intensity exercise [42], those with chronic disorders [42], and those with CVDs [43] or stroke [18]. This is because TC can be altered to make it appropriate for all fitness levels [2,13].

In this review, studies published on PubMed which have investigated the effects of TC on ANS modulation and therefore HRV are comprehensively summarized. Both consistent and inconsistent findings are presented and discussed. Since there were a limited number of relevant studies and only eleven articles were found which were deemed relevant and reliable to be included in this review, we have suggested further investigation regarding the roles of TC on HRV, to elucidate its possible clinical benefits in the future.

In order to have effectively presented and compared the results of each study, the meaning of the 'short term effects' of TC, in comparison to 'long term effects' had to be elucidated. With regards to the studies here, the short term or acute effects of TC were regarded as the change in HRV from pre to post TC exercise. This was either immediately after cessation of exercise, or after a certain period of time, usually 30 min. The 'long term effects' were regarded as a change in resting HRV over an extended period of time, a minimum of 3 months. The resting HRV was regarded as the HRV prior to any form of exercise. Only one study used 24 h HRV analysis [44], whereas the rest of the studies used short term measurements [3,4,9,12,21,25,45–48].

1.1. Beneficial acute effects of Tai Chi on heart rate variability

Five cross - sectional studies observed the change in HRV in TC/TCQ experienced practitioners from pre to post TC [3,12,21,25,47]. A summary of these studies is shown in Table 1. These studies demonstrated that TC could acutely enhance parasympathetic/vagal modulation [12,47], and reduce the sympathetic modulation [3,21,25], and hence increase the HRV. Väänänen et al. [12] showed that TCQ could acutely increase the HRV in both elderly TCQ experienced men, and young physical education male students [12]. The effects of TC on ANS modulation, irrespective of the breathing frequency was investigated by Lu and Kuo [47]. They found that the ability of TC to acutely enhance the vagal modulation was not solely due to the breathing frequency of the practitioners [47].

Similarly, Motivala et al. [4] also demonstrated that TC can acutely decrease the sympathetic modulation. In this study, the change in preejection period (PEP) was measured rather than HRV. PEP is inversely correlated with sympathetic activity [4,49], and was recorded throughout two 10-min periods, pre and post 20 min of either TCCh, passive rest, or slow moving exercise. This latter group was included to ensure any changes in PEP were due to the overall effects of TCCh rather than just the physical aspects. PEP significantly increased following the task period in the TCCh group only. These findings indicated that TCCh could acutely decrease sympathetic modulation [4].

Chang et al. [45] also investigated the acute effects of TC on HRV immediately following exercise every 3 months over a 9 month period (Table 1). They also concluded that TC can enhance the vagal modulation, and reduce the sympathetic modulation in the short term. In the study by Väänänen et al. [12], the HRV was acutely increased in the TC naïve participants' first TC experience. On the contrary, in the study by Chang et al. [45], it took over 6 months of practise by the TC naïve participants before these positive short term effects of TC on HRV frequency domain parameters (representing parasympathetic and sympathetic modulation) became significant [45] (Table 1). These findings suggest that a TC beginner may not benefit from any changes in ANS modulation following TC exercise until they are fluent in TC practise. Evidently, further studies are required to investigate the exact duration of TC practise a beginner requires before acute benefits on ANS modulation and HRV are seen following TC practise.

1.2. Beneficial effects of Tai Chi on resting heart rate variability

There are only two studies indicated beneficial effects of extended TC practise on resting HRV (Table 2). One of these was a cross sectional study, in which no TC was performed [46]. Instead, two groups of participants, one a TC naïve sedentary control group (SCG), and one a TC practitioner group, performed movements designed to imitate daily activities. Participants rested, then executed a sustained isometric contraction (SIC), and then stood. Firstly, greater parasympathetic modulation was displayed in the TC group compared to the SCG at rest. These findings indicated a potential benefit of long term TC practise. Since the parasympathetic modulation was higher at *rest* in the TC practitioners (before doing any exercise), this could indicate extended TC practise may lead to beneficial long term effects on resting HRV [46]. Likewise, significantly lesser sympathetic modulation, and greater parasympathetic modulation was demonstrated during the SIC in the TC group [46].

In addition, this study also presented indications of further possible benefits of extended TC practise. Practitioners in this study demonstrated natural breathing rates of 6–8 breaths per min. This slower-than normal breathing rate of the practitioners could suggest that they had adopted a slower breathing pattern in their everyday lives as a consequence of extended TC practise. Since slow and deep breathing alone can enhance HRV [34–36], the long term adoption of this breathing manner could be another possible benefit of extended TC practise.

The second study which found positive effects of TCC on resting HRV, was the 3 month longitudinal study by Audette et al. [9] (Table 2). They incorporated three groups, a brisk walking group, TC group, and a SCG, and compared the resting HRV parameters at baseline to those at 3 months. After three months, there was a significant enhancement in the nHFP, and decrement in nLFP when compared to baseline in the TCC group only, signifying enhanced parasympathetic modulation, and decreased sympathetic modulation [9].