Review Article

A Systematic Review and Meta-Analysis of Tai Chi Training in Cardiorespiratory Fitness of Elderly People

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Objectives. The purpose of this study was to investigate the influence of Tai Chi on cardiorespiratory fitness (CRF) in elderly people using meta-analysis. Methods. This study used seven electronic databases and data retrieved from randomized controlled trials (RCTs) investigating the role of Tai Chi on CRF in the elderly. All these 24 RCTs were screened and selected from 7 literature databases. The Stata 11.2 software (StataCorp, USA) was used for the meta-analysis, subgroup analysis, and bias test, while the Cochrane Collaboration’s tool was used for the assessment of the risk of bias (RoB). 4 researchers independently participated in sample selection, data extraction, and RoB assessment. Results. Following the inclusion criteria, 24 eligible studies were included in our analysis. The meta-analysis indicated that Tai Chi practice significantly increased the maximum rate of oxygen consumption (VO₂ max) (weighted mean difference (WMD) = 3.76, 95% CI: 1.25 to 6.26, P < 0.1), leading to an overall reduction in the heart rate (HR) (WMD = −1.84, 95% CI: −2.04 to −1.63, P ≤ 0.001) and an increase in the O₂ pulse (WMD = 0.94, 95% CI: 0.60 to 1.28, P ≤ 0.001) in individuals who practiced Tai Chi regularly compared with those who did not. The subgroup analysis suggested that overall in those who practiced Tai Chi, males (WMD = 1.48, 95% CI: 0.85 to 2.12, P ≤ 0.001) had higher O₂ pulse than females (WMD = 0.73, 95% CI: 0.33 to 1.12, P ≤ 0.001). The subgroup analysis also showed an increase in the vital capacity (VC) (WMD = 316.05, 95% CI: 239.74 to 392.35, P ≤ 0.001) in individuals practicing Tai Chi. When the samples were further stratified by Tai Chi practicing time, the subgroup analysis suggested that individuals practicing Tai Chi over a period of 24 weeks showed no significant difference in VC (WMD = 82.95, 95% CI: -98.34 to 264.23, P = 0.370), while those practicing Tai Chi over a period of 48 weeks showed a significant increase (WMD = 416.62, 95% CI: 280.68 to 552.56, P ≤ 0.001). Furthermore, the subgroup analysis demonstrated that the increase in VC is significantly correlated with the Tai Chi practicing time (WMD = 344.97, 95% CI: 227.88 to 442.06, P ≤ 0.001). Conclusion. Regular Tai Chi practice could improve the CRF in the elderly, as indicated by significant improvement in indicators including VO₂ max, O₂ pulse, VC, and HR. However, gender and practice time might influence the overall beneficial outcomes.

1. Introduction

Cardiorespiratory fitness (CRF) represents the capacity of the circulatory and respiratory systems to supply oxygen during sustained physical activity. Natural processes such as aging, senescence, and chronic diseases [1] often lead to an overall decline in the CRF [2], which is more pronounced in males than in females [3]. A positive correlation was observed between a steady decrease in CRF over time and an increase in the total mortality [4]. Maximal oxygen uptake (VO₂ max), which decreases at an average rate of 1% per year after the age of 25, is a remarkable predictor of CRF [5]. High incidence of cardiovascular and respiratory diseases is particularly common in populations over the age of 45 [6]. Moreover, studies have found a direct correlation between poor CRF and increased risk of stroke (occurrence and recurrence) [7], atherosclerosis [8], type 2 diabetes [9], and disturbed cerebral blood flow (CBF), which can potentially impact brain structural and functional integrity and cognitive function [10].
Treatment options for cardiopulmonary rehabilitation include aerobic exercises [11], acupuncture [12], and the application of Chinese medicine [13]. However, the factors such as fear of needles and invasive therapeutic methods, and high medical expenses contributed to the avoidance of cardiopulmonary rehabilitation among patients. Aerobic exercise is widely recognized for its role in improving cardiac health and thus has always been recommended by doctors as a treatment option for cardiopulmonary rehabilitation aimed at prevention and recovery from preexisting diseases. Tai Chi involves slow-paced aerobic exercises with moderate intensity and combines delicate physical movements with rhythmic breathing [14], allowing adults of all age groups to participate. Thus, Tai Chi has gained popularity over the past years. In recent years, an increasing number of randomized control trials evaluating the beneficial effects of Tai Chi on balance function [15], fibromyalgia [16], and cognitive control trials evaluating the beneficial effects of Tai Chi on CRF in the elderly people was searched in 7 databases, including PubMed, Web of Science, EMBASE, Cochrane Library, Chinese Scientific Citation Database (CSCD), China National Knowledge Infrastructure Database (CNKI), and WanFang Database. The date of literature searching is from inception to June 9, 2021. Relevant systematic reviews and the reference list of included articles were searched to identify any further relevant studies.

The search keywords used in Chinese were as follows: “Taiji,” “cardiorespiratory function,” and “aged.” Based on similar studies [18], the search keywords in English used were as follows (example from PubMed database quoted below):

#1 Taiji [Mesh] OR Tai Chi [Title/Abstract] OR Chi, Tai [Title/Abstract] OR Tai Ji Quan [Title/Abstract] OR Ji Quan, Tai [Title/Abstract] OR Quan, Tai Ji [Title/Abstract] OR Taiji OR Taijiquan [Title/Abstract] OR T'ai Chi [Title/Abstract] OR Tai Chi Chuan [Title/Abstract].


#3 Aged [Mesh] OR elderly [Title/Abstract].

#4 Control OR comparison OR controlled trial.

#5 AND #2 AND #3 AND #4.

2.2. Study Selection Criteria. The articles were primarily screened based on their titles and abstracts. Then, the full texts of these articles were further reviewed by 4 researchers. In the case of disagreement for study inclusion, the researchers would discuss until a consensus was reached. Studies were considered eligible if:

(1) The mean age of patients was >50 years.
(2) Tai Chi training was the sole intervention method irrespective of the style.
(3) The outcomes included CRF parameters such as VO2, vital capacity (VC), and heart rate (HR).
(4) Paired groups, including the control group (sedentary lifestyle) and the comparison group (practicing other forms of exercise such as walking or maintaining usual physical activity), were included in the study.
(5) Language of publication was either English or Chinese.
(6) The study was an RCT.

Studies were excluded if:

(1) The study was a review, case study, or report describing a method or protocol.
(2) The study cases were already included in another study we have selected.
(3) Missing control groups or comparison groups.
(4) Incomplete data.
(5) The intervention group had a combinatorial exercise regime involving other forms of exercise training (e.g., strength training).

2.3. Data Extraction and Risk-of-Bias (RoB) Assessment. Two independent researchers participated in the data extraction. In case of disagreement, the researchers would discuss until a consensus was reached. The key data extracted from each study were as follows: (1) author details; (2) year of publication; (3) country; (4) sample size (M/F); (5) mean age (Tai Chi group/control group); (6) style of Tai Chi practiced; (7) frequency of exercise; (8) daily duration of...
exercise; (9) total time of Tai Chi training; and (10) the outcomes of CRF should include at least of the following core outcomes such as VO2 max (mL·kg\(^{-1}\)·min\(^{-1}\)), VC (mL), HR (beats per min), and O2 pulse (mL·beat\(^{-1}\)).

The two researchers independently assessed the methodologies of the studies using the Cochrane Collaboration’s tool for the assessment of RoB. The RoB assessment involved random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome data, marking of incomplete outcome data, selective reporting, and screening of other existing biases.

2.4. Statistical Analysis. The Stata 11.2 software (StataCorp, USA) was used for conducting the meta-analysis. Regarding continuous variables, several analyses, such as combined effects, heterogeneity analysis, subgroup analysis, and publication bias analysis, were carried out. The calculated results were expressed as weighted mean difference (WMD). The I\(^2\) and \(\chi^2\) homogeneity tests were conducted before the combined effects were evaluated. When I\(^2\) < 50% or P > 0.1, the variables were considered to possess low heterogeneity. When I\(^2\) < 50% or P < 0.1, the variables were considered to possess high heterogeneity. A fixed meta-analysis was performed when I\(^2\) < 50%, and a random meta-analysis was performed when I\(^2\) ≥50%. The publication bias analysis was conducted using Egger’s and Begg’s plots in the Stata 11.2.

3. Results

3.1. Study Selection. A total of 471 articles were identified from the search results of the 7 electronic databases. A total of 126 articles were excluded due to duplicate representation (Figure 1). After reading the titles and abstracts, we rescreened the remaining 52 articles. We excluded 10 articles due to lack of inclusion of control group; 16 articles due to the presence of unrelated data not pertinent to this study; 1 article due to inclusion of non-elderly; and 1 article due to missing of information on CRF measurements. Finally, a total of 24 articles that met the eligibility criteria for the systematic review were included.

3.2. Characteristics of Selected Studies. The 24 articles selected for the meta-analysis reported data from 1995 to 2020 and represented individuals geographically localized in countries such as China, the Netherlands, Mexico, and the United States. The sample size of these studies ranged from 20 to 380. A total of 2155 participants were included, with ages ranging from 50 to 89. The most common frequency of Tai Chi training reported was 4 times per week (20%). The longest duration of Tai Chi practice reported was 11 years, and the shortest was 4 weeks (Table 1).

3.3. RoB Results. The results of the RoB of these RCTs are summarized in Figures 2 and 3, respectively. In summary, 6 studies (25%) showed low-risk bias due to random sequence generation; 5 studies (20%) showed low-risk bias attributed to allocation concealment; 24 studies (100%) exhibited low-risk bias due to blinding of the participants or personnel; 2 studies (8%) showed low-risk bias, which was attributed to blinding of the assessment outcomes; 20 studies (80%) showed a low-risk bias due to incompleteness of the outcome data; 1 study (4%) showed low-risk bias due to selective reporting; and 12 studies (48%) showed low-risk bias due to the presence of other factors or biases.

3.4. Meta-Analysis

3.4.1. Tai Chi for VO2 max. Two studies including 122 patients contributed to the meta-analysis of the VO2 max (Figure 4). Tai Chi training significantly increased the VO2 max compared with the control (WMD = 3.76, 95% CI: 1.25 to 6.26, P = 0.003). The I\(^2\) was 77.4%, heterogeneity \(\chi^2 = 13.26\) (d.f. = 3), and P = 0.004. There was substantial heterogeneity across the studies included in the meta-analysis.

3.4.2. Tai Chi for HR. 1,492 participants from 15 studies were used for the meta-analysis of HR. As shown in Figure 5, the HR was significantly reduced in participants who practiced Tai Chi compared with those who did not (WMD = -1.84, 95% CI: -2.04 to -1.63, P = 0.001). For these studies, I\(^2\) = 30.9%, \(\chi^2 = 31.83\) (d.f. = 22), and P = 0.008, indicating a low heterogeneity across these studies. The funnel plots for several outcomes were not fully symmetrical (Figure 6). The P value for Egger’s test was 0.026. The Z value for Begg’s test was 0.79 (Figure 6).

3.4.3. Tai Chi for O2 pulse. 267 participants from 4 studies were used for the meta-analysis of O2 pulse. As shown in Figure 7, the O2 pulse was significantly increased in participants who practiced Tai Chi compared with those who did not (WMD = 0.94, 95% CI: 0.60 to 1.28, P = 0.001). For these studies, I\(^2\) = 16.5%, \(\chi^2 = 8.38\) (d.f. = 7), and P = 0.300, indicating a low heterogeneity across these studies.

The subgroup analysis was performed to compare the effects of Tai Chi across different genders in the test population. The results suggested that Tai Chi practice in males resulted in a significant increase in the O2 pulse (WMD = 1.48, 95% CI: 0.85 to 2.12, P = 0.001) (Figure 8). No heterogeneity was observed in these studies that included male participants, as indicated by I\(^2\) = 0.0% (Figure 8). Similarly, Tai Chi practice in females significantly increased the O2 pulse as well (WMD = 0.73, 95% CI: 0.33 to 1.12, P = 0.001) (Figure 9). No heterogeneity was observed in these studies that included female participants (I\(^2\) = 0.0%) (Figure 9).

3.4.4. Tai Chi for VC. 748 participants from 8 studies were used for the meta-analysis of VC. As shown in Figure 10, the VC was significantly increased in participants who practiced Tai Chi compared with those who did not (WMD = 13.65, 95% CI: 239.74 to 392.35, P = 0.001). For these studies, I\(^2\) = 40.7%, heterogeneity \(\chi^2 = 5.17\) (d.f. = 9), and P = 0.086, indicating a low heterogeneity across the studies. The funnel plots for several outcomes were not fully symmetrical.
Records through database searching n=471
PubMed=163; Cochrane=137
Embase=29; Web of Science=31
CNKI=39; VIP=19; Wang Fang=53

Records after duplicates removed n=345

Records excluded by titles and abstracts n=293

Full-text articles assessed for eligibility n=52

No control group n=10
Not required data n=16
Not including CRF measurement n=1
No older people n=1

Meeting the inclusion criteria n=24

Trials included in the systematic review n=24

Figure 1: Flowchart representing the study selection criteria.

Table 1: Details of studies that were included in the meta-analysis.

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Country and languages</th>
<th>Sample size (M/F)</th>
<th>Mean age (T/C)</th>
<th>Control group</th>
<th>Tai Chi style</th>
<th>Frequency</th>
<th>Daily time</th>
<th>Duration</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lan et al., 1996 [19]</td>
<td>China English</td>
<td>76 40/36</td>
<td>69.3 ± 3.9</td>
<td>NC</td>
<td>Classical Yang’s Tai Chi</td>
<td>4.3 ± 1.3 time per week</td>
<td>20 min of warm up, 24 min Tai Chi, 10 min of cool down</td>
<td>11.8 ± 5.6 years</td>
<td>HR, O2 pulse</td>
</tr>
<tr>
<td>Zheng et al., 2019 [20]</td>
<td>China English</td>
<td>170 52/118</td>
<td>61.01 ± 5.20/60.73 ± 6.05</td>
<td>Physical activities</td>
<td>24-movement Yang-style Tai Chi</td>
<td>5 time per week</td>
<td>10 min of warm up, 45 min Tai Chi, 5 min of cool down</td>
<td>12 weeks</td>
<td>VC</td>
</tr>
<tr>
<td>Lu and Kuo, 2003 [21]</td>
<td>China English</td>
<td>40 14/26</td>
<td>56.3 ± 8.5/52.8 ± 7.5</td>
<td>No physical exercise</td>
<td>Classical Yang’s Tai Chi</td>
<td>NC</td>
<td>10 min of warm up, 20 min Tai Chi, 10 min of cool down</td>
<td>NC</td>
<td>HR</td>
</tr>
<tr>
<td>Mendoza-Núñez et al., 2018 [22]</td>
<td>Mexico English</td>
<td>85</td>
<td>68.2 ± 6.6/67.4 ± 4.7</td>
<td>No physical exercise</td>
<td>Eight-form easy Tai Chi for elderly adults</td>
<td>5 time per week</td>
<td>10 min of warm up, 30 min Tai Chi, 5 min of cool down</td>
<td>24 weeks</td>
<td>HR</td>
</tr>
<tr>
<td>Author, year</td>
<td>Country and languages</td>
<td>Sample size (M/F)</td>
<td>Mean age (T/C)</td>
<td>Control group</td>
<td>Tai Chi style</td>
<td>Frequency</td>
<td>Daily time</td>
<td>Duration</td>
<td>Outcome</td>
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<tr>
<td>Sun et al., 2019 [23]</td>
<td>China English</td>
<td>120/68/52</td>
<td>65.2 ± 9.2/66.4 ± 10.0</td>
<td>Activities of daily living</td>
<td>24-movement Yang-style Tai Chi</td>
<td>3 times per week</td>
<td>30–40 min</td>
<td>NC</td>
<td>VC</td>
</tr>
<tr>
<td>Lai et al., 1995 [24]</td>
<td>China English</td>
<td>84/44/40</td>
<td>64 ± 9</td>
<td>NC</td>
<td>Classical Yang's Tai Chi</td>
<td>5.0 ± 1.1 times per week</td>
<td>20 min of warm up, 24 min Tai Chi, 10 min of cool down</td>
<td>24 weeks</td>
<td>HR, O₂ pulse, VO₂ max</td>
</tr>
<tr>
<td>Lan et al., 2008 [25]</td>
<td>China English</td>
<td>69/34/35</td>
<td>64.0 ± 6.8/64.7 ± 7.4</td>
<td>No physical exercise</td>
<td>Classical Yang's Tai Chi</td>
<td>NC</td>
<td>240 weeks</td>
<td>HR, O₂ pulse</td>
<td></td>
</tr>
<tr>
<td>Logghe et al., 2009 [26]</td>
<td>NED English</td>
<td>269/78/191</td>
<td>76.8 ± 4.6/77.5 ± 4.7</td>
<td>Usual care</td>
<td>10-movement Yang-style Tai Chi</td>
<td>2 times per week</td>
<td>1 hour</td>
<td>13 weeks</td>
<td>HR</td>
</tr>
<tr>
<td>Ma et al., 2019 [27]</td>
<td>US English</td>
<td>52/18/34</td>
<td>64.85 ± 7.62/64.15 ± 7.69</td>
<td>Usual care</td>
<td>NC</td>
<td>2 times per week</td>
<td>NC</td>
<td>24 weeks</td>
<td>HR</td>
</tr>
<tr>
<td>Cui and Fu, 2017 [28]</td>
<td>China English</td>
<td>140</td>
<td>68.4 ± 3.2</td>
<td>Slow walking exercise</td>
<td>NC</td>
<td>4 times per week</td>
<td>30–60 min</td>
<td>24 weeks</td>
<td>HR</td>
</tr>
<tr>
<td>Wang et al., 2016 [29]</td>
<td>US English</td>
<td>28/7/21</td>
<td>89.73 ± 6.31/87.23 ± 6.71</td>
<td>NC</td>
<td>10-form Tai Chi</td>
<td>2 times per week</td>
<td>10 min of warm up, 45 min Tai Chi, 5 min of cool down</td>
<td>12 weeks</td>
<td>HR</td>
</tr>
<tr>
<td>Zhang et al., 2020 [30]</td>
<td>China English</td>
<td>36</td>
<td>59.65 ± 8.42/62.21 ± 7.76</td>
<td>Physical activities</td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
<td>12 weeks</td>
<td>HR</td>
</tr>
<tr>
<td>Wang et al., 2001 [31]</td>
<td>China Chinese</td>
<td>115/60/55</td>
<td>68.81 ± 5.72/67.07 ± 4.98</td>
<td>No physical exercise</td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
<td>HR</td>
<td></td>
</tr>
<tr>
<td>Ma, 2015 [32]</td>
<td>China Chinese</td>
<td>27</td>
<td>60.86 ± 2.54/60.43 ± 1.90</td>
<td>No physical exercise</td>
<td>NC</td>
<td>NC</td>
<td>24/48 weeks</td>
<td>VC, HR</td>
<td></td>
</tr>
<tr>
<td>Liu and Jin, 2010 [33]</td>
<td>China Chinese</td>
<td>20/10/10</td>
<td>61.7 ± 4.3</td>
<td>No physical exercise</td>
<td>24-movement Yang-style Tai Chi</td>
<td>4 times per week</td>
<td>10 min of warm up, 40 min Tai Chi, 10 min of cool down</td>
<td>8 weeks</td>
<td>VC</td>
</tr>
<tr>
<td>Li, 2008 [34]</td>
<td>China Chinese</td>
<td>60</td>
<td>66.1 ± 4.6/65.5 ± 4.8</td>
<td>No physical exercise</td>
<td>NC</td>
<td>4 times per week</td>
<td>40–60 min</td>
<td>48 weeks</td>
<td>HR</td>
</tr>
<tr>
<td>Peng, 2006 [35]</td>
<td>China Chinese</td>
<td>380/180/200</td>
<td>NC</td>
<td>No physical exercise</td>
<td>NC</td>
<td>3 times per week</td>
<td>30 min</td>
<td>240 weeks</td>
<td>VC</td>
</tr>
<tr>
<td>Yuan, 2015 [36]</td>
<td>China Chinese</td>
<td>100</td>
<td>61.18 ± 8.916/61.26 ± 8.813</td>
<td>No physical exercise</td>
<td>NC</td>
<td>3 times per week</td>
<td>30 min</td>
<td>96 weeks</td>
<td>VC</td>
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<tr>
<td>Yan, 2013 [37]</td>
<td>China Chinese</td>
<td>47/24/23</td>
<td>&gt; 65</td>
<td>No physical exercise</td>
<td>24-movement Tai Chi</td>
<td>NC</td>
<td>30 min</td>
<td>NC</td>
<td>VC</td>
</tr>
<tr>
<td>Lai et al., 2009 [38]</td>
<td>China Chinese</td>
<td>64</td>
<td>68.4 ± 2.1/67.9 ± 2.4</td>
<td>No physical exercise</td>
<td>Running training</td>
<td>NC</td>
<td>NC</td>
<td>48 weeks</td>
<td>HR</td>
</tr>
<tr>
<td>Xu and Wen, 1997 [39]</td>
<td>China Chinese</td>
<td>34/17/17</td>
<td>64.6 ± 3.9/66.7 ± 7.4</td>
<td>No physical exercise</td>
<td>Yang-style Tai Chi</td>
<td>7 times per week</td>
<td>60 min</td>
<td>4 weeks</td>
<td>VC, HR</td>
</tr>
<tr>
<td>Author, year</td>
<td>Country and languages</td>
<td>Sample size (M/F)</td>
<td>Mean age (T/C)</td>
<td>Control group</td>
<td>Tai Chi style</td>
<td>Frequency</td>
<td>Daily time</td>
<td>Duration</td>
<td>Outcome</td>
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<tr>
<td>Tu, 2005 [40]</td>
<td>China Chinese</td>
<td>32 NC</td>
<td></td>
<td>Running training</td>
<td>NC</td>
<td>3 times per week</td>
<td>12 min</td>
<td>10 weeks</td>
<td>HR</td>
</tr>
<tr>
<td>Lin and Huang, 2002 [41]</td>
<td>China Chinese</td>
<td>69 50–62</td>
<td>Aerobic exercise</td>
<td>24-movement Yang-style Tai Chi</td>
<td>4 times per week</td>
<td>40 min</td>
<td>24 weeks</td>
<td>HR</td>
<td></td>
</tr>
<tr>
<td>Cheng et al., 2001 [42]</td>
<td>China Chinese</td>
<td>38 18/20</td>
<td>58–70</td>
<td>NC</td>
<td>Classical Yang's Tai Chi</td>
<td>4.6 ± 1.3 times per week</td>
<td>20 min of warm up, 24 min Tai Chi, 10 min of cool down</td>
<td>NC</td>
<td>HR, VO₂max, O₂ pulse</td>
</tr>
</tbody>
</table>

Random sequence generation (selection bias)
Allocation concealment (selection bias)
Blinding of participants and personnel (performance bias)
Blinding of outcome assessment (detection bias)
Incomplete outcome data (attrition bias)
Selective reporting (reporting bias)
Other bias
0 25 50 75 100 (%)

Low risk of bias
Unclear risk of bias
High risk of bias

Figure 2: Graph representing the risk of bias (RoB).

Figure 3: Summary of the risk of bias (RoB).
NOTE: Weights are from random effects analysis

Overall (I-squared = 77.4%, p = 0.004)

Study
Cheng (2001)
C. Wang (2001)

- WMD (95% CI)
  7.90 (4.44, 11.36)
  4.60 (2.97, 6.23)
  1.30 (-2.07, 4.67)
  7.90 (4.44, 11.36)

- Weight
  20.61
  28.68
  21.02
  100.00


Overall (I-squared = 30.9%, p = 0.080)

Study
Inge H. J. Logghe (2009)
Wang (2001)
Ching Lan (1996)
Cheng (2001)

- WMD (95% CI)
  -2.97 (-7.65, 1.71)
  -2.18 (-8.42, 4.06)
  -0.99 (-3.00, 1.02)
  -3.06 (-7.41, 1.29)

- Weight (%)
  0.19
  0.11
  1.55
  0.22


- WMD (95% CI)
  -5.95 (-12.56, 0.66)

- Weight (%)
  0.09


- WMD (95% CI)
  -0.20 (-4.88, 4.48)

- Weight (%)
  0.19


Figure 4: Forest plot representing the effect of Tai Chi on the VO$_2$ max.

Figure 5: Forest plot representing the effect of Tai Chi on HR.
P value for Egger’s test was \( P = 0.464 \), and Z value for Begg’s test was 0.09.

The subgroup analysis was performed to compare the effects of Tai Chi practice of different exercise durations (Figure 12). The results suggested that no statistically significant difference existed between the control and comparison groups with participants undergoing Tai Chi training less than 24 weeks (WMD = 82.95, 95% CI: -98.34 to 264.23, \( P = 0.370 \)).

The VC was increased in the Tai Chi practice group with a duration of 48 weeks compared with that of the control group (WMD = 416.62, 95% CI: 280.68 to 552.56, \( P \leq 0.001 \)).

In these studies, \( I^2 = 27.9\% \), indicating a low heterogeneity across the studies (Figure 13).

The Tai Chi training for mixed duration significantly increased the VC compared with the control (WMD = 344.97, 95% CI: 227.88 to 442.06, \( P \leq 0.001 \)). There was no heterogeneity across the studies included in the meta-analysis (\( I^2 = 3.9\% \)) (Figure 14).

4. Discussion
Tai Chi is originated from traditional Chinese martial arts and medicine [43] and was practiced to maintain physical
and mental health. The unity of opposites representing yin-yang is also an integral part of the symbol representing Tai Chi. Tai Chi is also known as the “moving meditation” [44]. This study aimed to evaluate the effectiveness of Tai Chi in improving CRF in the elderly using a meta-analysis approach, which included 2155 participants from 24 RCTs. Based on our analyses, we concluded that overall the Tai Chi training could significantly improve the CRF in the elderly. However, the beneficial effects of Tai Chi are influenced by many factors, including gender and practice time.

**VO$_2$ max** and O$_2$ pulse were indicators of comprehensive circulatory and respiratory ability; in particular, VO$_2$ max was the gold parameters of CRF. The parameters of cardiopulmonary fitness are various, such as maximal minute ventilation (MMV) and cardio output (CO). However, there were very few literatures including MVV and CO. Thus, we were unable to perform meta-analysis. Blood pressure was a vital sign, and the change in blood pressure was not influenced by a single factor of Tai Chi training. Therefore, blood pressure was not selected as a CRF indicator in this study.

4.1. **VO$_2$ max** The VO$_2$ max represents the oxygen consumed during a maximum intensity exercise, which can be analyzed using a cardiopulmonary exercise test (CEPT). The VO$_2$ max is an indicator of CRF [45]. The results of the meta-analysis suggested that Tai Chi training could significantly improve the VO$_2$ max in individuals who practiced Tai Chi compared

<table>
<thead>
<tr>
<th>Study ID</th>
<th>WMD (95% CI)</th>
<th>% Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ching Lan (1996)</td>
<td>1.40 (0.24, 2.56)</td>
<td>30.24</td>
</tr>
<tr>
<td>Jin-Shin Lai (1995)</td>
<td>1.90 (0.83, 2.97)</td>
<td>35.35</td>
</tr>
<tr>
<td>Ching Lan (2008)</td>
<td>1.70 (0.32, 3.08)</td>
<td>21.28</td>
</tr>
<tr>
<td>Cheng (2001)</td>
<td>0.20 (-1.56, 1.96)</td>
<td>13.13</td>
</tr>
<tr>
<td>Overall (I-squared= 0.0%, p = 0.433)</td>
<td>1.48 (0.85, 2.12)</td>
<td>100.00</td>
</tr>
</tbody>
</table>

![Figure 8: Forest plot representing the effect of Tai Chi on O$_2$ pulse in males.](image)

<table>
<thead>
<tr>
<th>Study ID</th>
<th>WMD (95% CI)</th>
<th>% Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ching Lan (1996)</td>
<td>1.10 (0.41, 1.79)</td>
<td>33.18</td>
</tr>
<tr>
<td>Jin-Shin Lai (1995)</td>
<td>0.60 (-0.18, 1.38)</td>
<td>25.89</td>
</tr>
<tr>
<td>Ching Lan (2008)</td>
<td>0.50 (-0.23, 1.23)</td>
<td>29.81</td>
</tr>
<tr>
<td>Cheng (2001)</td>
<td>0.50 (-0.69, 1.69)</td>
<td>11.11</td>
</tr>
<tr>
<td>Overall (I-squared= 0.0%, p = 0.630)</td>
<td>0.73 (0.33, 1.12)</td>
<td>100.00</td>
</tr>
</tbody>
</table>

![Figure 9: Forest plot representing the effect of Tai Chi on O$_2$ pulse in females.](image)
with those who did not (WMD = 3.76, 95% CI: 1.25 to 6.26, \( P = 0.003 \)). The improvement of \( VO_2 \text{max} \) might be attributed to the distinct movement patterns performed during the practice of Tai Chi. Tai Chi training requires the center of gravity to move down, the waist to rotate slowly, and the upper and lower limbs to coordinate simultaneously. The overall rhythm of Tai Chi training is regular, involving movements of the abdominal muscles, pectoralis major, and sternocleidomastoid muscle (breathing muscles). The Tai Chi movements also involve trained and rhythmical breathing. The fusion of body exercise and effective breathing enhances the contractility and endurance of the diaphragm.

Although \( VO_2 \text{max} \) is currently the “gold standard” for CRF, there are very few published articles that used CEPT to evaluate the efficacy of Tai Chi. This may be due to the fact that the presence of preexisting chronic diseases in the elderly hindered the performance of CEPT, as this test method involves high-risk events such as palpitations, loss of consciousness, and, more seriously, a sudden death.
4.2. HR. HR is a commonly measured vital sign, which is regulated by the autonomic nervous system [46]. Our analyses showed that the Tai Chi training significantly reduced the HR in those who practiced Tai Chi (WMD = −1.84, 95% CI: −2.04 to −1.63, \( P \leq 0.001 \)). A previous study has proved that Tai Chi could enhance parasympathetic activity and decrease sympathetic activity [47]. The neurophysiological mechanism of Tai Chi may involve the activation of the parasympathetic nervous system, which is known to decrease HR [48] and play an active role in relieving anxiety and fear [49]. Elevated HR can increase the risk of sudden death [50]. Based on these studies, we believe that long-term and regular Tai Chi training could extend the life span of the elderly and increase the happiness index of life for them.

According to Begg’s test \( (P = 0.026) \) and the funnel plot, there is a significant bias in the published studies, probably due to the fact that only positive results are likely to be published. Nevertheless, we suppose that the results accurately represent the real-life situation, as a recently published study report confirmed the results [51].

4.3. \( O_2 \) pulse. The \( O_2 \) pulse reflects the oxygen intake per heartbeat and is represented by the ratio of oxygen consumption to HR. The increase in \( O_2 \) pulse indicates superior cardiopulmonary fitness during exercise. Our results suggested that Tai Chi could improve the \( O_2 \) pulse in those who practiced Tai Chi (WMD = 0.94, 95% CI: 0.60 to 1.28,
beneficial effect on the VC may not be evident. Overtraining often reduces skeletal muscle strength [59] and induces oxidative stress [60], which may trigger a ceiling effect. According to our subgroup analysis, VC was higher in individuals who underwent Tai Chi training for 48 consecutive weeks (WMD = 416.62, 95% CI: 280.68 to 552.56, \( P \leq 0.001 \)) than those who practiced Tai Chi for 24 consecutive weeks (WMD = 82.95, 95% CI: -98.34 to 264.23, \( P = 0.370 \)). The increase in VC for individuals practicing Tai Chi for 24 weeks was reversed when the training was done over a 48-week period. We hypothesized that the improvement of VC could only be achieved by compounding the effects of exercise over a longer training duration. However, VC turned out to be an indicator with reduced sensitivity, which changed significantly with long durations of Tai Chi training. Tai Chi involves aerobic exercises of low-to-moderate intensity. Determining the training duration may provide better clinically significant insight. According to Begg’s test (\( P = 0.464 \)) and the funnel plot, there was no bias in the published studies.

5. Conclusions

To the best of our knowledge, our study is the first to report the correlation between CRF and Tai Chi training in the elderly using meta-analysis. Our findings suggest that Tai Chi training effectively improved the CRF in older adults. We demonstrated that practicing Tai Chi could benefit body function by enhancing factors such as VO2\(_{\text{max}}\), O2 pulse, VC, and HR. Additionally, we found that gender and practice time can also influence the outcome of Tai Chi practice. Compared with females, males may benefit to a greater extent showing better CRF. We also demonstrated that longer practice time could improve the CRF. Thus, this study contributes to the existing knowledge and provides a new direction for further study.

5.1. Limitations. There were several limitations of this study. (1) Although we included studies from multiple databases, we only considered studies published in English and Chinese, which might undergo the risk of miss studies; (2) limiting the number of studies by our inclusion criteria may lead to bias; and (3) The quality of included literature was low methodological. The descriptions of the 18 studies regarding the random sequence generation were not detailed. There were no descriptions of allocation concealment in 19 studies. 22 studies have the risk in blinding of the assessment outcomes. These limitations could possibly attribute to multiple factors. First, how Tai Chi could relate to CRF has not attracted enough attention. Second, Tai Chi as the exercise therapy was unable to be blinded. Lastly, Tai Chi training requires disciple and it is rather difficult to adhere to a regular training regimen. (4) The subgroup analysis of the control group was not performed, which may further contribute to biased results. Therefore, additional RCTs with larger sample sizes would be essential in future studies.
Data Availability
The data for supporting this review were taken from previously reported and datasets, which have been cited. Data are available upon request to the corresponding author.

Conflicts of Interest
The author(s) declare that there are no conflicts of interest regarding the publication of this paper.

Authors’ Contributions
Yulong Wei contributed to developing the overall design of study. Tianyang Tan performed the literature review from relevant databases, assessed the quality of the study, and wrote the manuscript under the guidance of Yulong Wei. Tianyang Tan and Yanyan Meng contributed equally to this article. Yanyan Meng was the Co-first author. Chengchao Wang and Chaoyang Zhang contributed to screening the articles independently. Meng Liu and Xirui Zhao contributed to data extraction and reviewed methodological quality independently. Yulong Wei arbitrated the disagreements. Jiaxuan Lyu and Tianyi Lyu supported their valuable advice and optimized the language accuracy.

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References
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