Comparison of Effects of Tai Chi Chuan and Western Exercises on Cognitive Functions in Older Adults: Systematic Review and Meta-analysis

M.-T. Wu $^{1,2,*}$, P.-F. Tang $^{1,3}$, K.-Y. Lin $^1$

$^1$ School and Graduate Institute of Physical Therapy, National Taiwan University, Taiwan
$^2$ Physical Therapy Center, Cardinal Tien Hospital Yonghe Branch, Taiwan
$^3$ Graduate Institute of Brain and Mind Sciences, National Taiwan University, Taiwan
Background

- **Dementia**
  - Prevalence
    - Adults older than 65 y/o: 5-6%
    - Doubles every 5 years after the age of 65
  - Alzheimer’s disease (AD) is most common type of dementia

- **Mild cognitive impairment (MCI)**
  - Prevalence: 10% in older adults
  - Rate of transition from MCI to dementia: 10% to 20% per year

- **Prevention of dementia and MCI is an important global health issue.**

(Boyle et al., 2009; Capizzano et al., 2004; Corder et al., 1993; WHO, 2012)
Aerobic exercise (*western exercise, WE*) improves cognitive function in healthy older adults, including attention, processing speed, executive function, and memory. (Colcombe & Kramer, 2003)

Potential mechanisms of WE effects
- WE improves cardiovascular endurance, which in turn may result in cognitive function improvement. (Moller et al., 2011; Ramirez-Velez et al., 2011)

How about traditional Eastern exercises?
- Tai Chi Chuan (TCC) also improves aerobic capacity and cognitive function in older adults. (Hui et al., 2009; Lan et al., 2008; Taylor-Piliae, 2008, Taylor-Piliae et al., 2011)
To investigate whether WE and TCC exercises result in differential beneficial effects on different cognitive functions in older adults, using systematic review and meta-analysis

Hypothesis: WE and TCC exercises may involve different mental processes, and thereby may cause differential effects on different domains of cognitive functions in older adults
Methods

- **Systematic search strategy:**
  - Literature published before August 2012.
  - Databases: MEDLINE, PubMed, CINAHL, CENTRAL, PsycINFO, SPORTDiscus, CEPES.
  - Key words:
    - Tai Chi, Tai Chi Chuan, aerobic exercise, western exercise, strength training, cognition, and cognitive function
  - Inclusion criteria:
    - Participants: over 65 years old
    - Language: English or Chinese
    - RCT design, both TCC and WE interventions were used and assigned to either the experimental or control group
    - Cognitive or neuropsychological outcome measures
Methods (con’t)

- Neuropsychological outcome measures
  - Overall cognitive function
    - Clinical Dementia Rating scale (CDR)
    - Alzheimer's Disease Assessment Scale- Cognitive Subscale (ADAS-cog)
    - Cantonese version of Mini-Mental State Examination (CMMSE)
  - Working memory
    - Category verbal fluency Test/animal-naming verbal fluency test
    - Digit span forward & backward
  - Executive function
    - Trail Making Test Part A (TMT-A) & B (TMT-B)
  - Others
    - Stroop Test, Verbal Learning Test, Clock-Drawing Test, delay recall, visual span, etc.
Methods (con’t)

- Methodological quality assessment of studies:
  - Two researchers independently rated the quality of studies
  - Quality of included studies: Physiotherapy Evidence Database Scale (PEDro) score ≥ 4 (de Morton, 2009)

- Meta-analysis
  - Review Manager Version 5.0.
  - $\alpha = 0.05$
  - $I^2 < 25\%$: low heterogeneity, fixed effect model (Higgins et al., 2003)
The systematic search yielded eighteen studies, among which only three randomized controlled trials met the established criteria and were included in meta-analysis.

A total of 202 older subjects received Tai Chi and 263 older subjects received WE.

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Subjects</th>
<th>N</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor-Pilia et al., 2010</td>
<td>Community elderly</td>
<td>TCC : 37, WE : 39</td>
<td>70.6 ± 5.9, 68.5 ± 5.0</td>
</tr>
<tr>
<td>Lam et al., 2011</td>
<td>Older adults with mild cognitive impairment</td>
<td>TCC : 135, WE : 194</td>
<td>77.2 ± 6.3, 78.3 ± 6.6</td>
</tr>
<tr>
<td>Mortimer et al., 2012</td>
<td>Community elderly</td>
<td>TCC : 30, WE : 30</td>
<td>67.3 ± 5.3, 67.8 ± 5.0</td>
</tr>
<tr>
<td>Authors, year</td>
<td>Intervention</td>
<td>Intensity Frequency/Duration</td>
<td>Results</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------</td>
<td>-----------------------------</td>
<td>---------</td>
</tr>
</tbody>
</table>
| Taylor-Pilia, et al., 2010 | TCC: 12-form (0~24 wk.) and 24-form Yang style (24~48 wk.) | TCC: 45 min × 4~5 sessions/wk 48 wks | • Both TCC and WE group showed significant within-group improvements in semantic fluency.  
• At 48-wk, TCC group had better function on **digit span backward** than the WE group. The cognitive improvements observed in Tai Chi group were maintained through 12 month. |
| Lam et al., 2011 | TCC: 24-form | 30 min × 3 sessions/wk 12 wks | • Both TCC and WE group showed the same significant improvements on CMMSE, ADAS-cog, SMC, delay recall, verbal fluency, and TMT-A.  
• At follow-up. The TCC group also showed improvements on visual span and CDR. To compare the deterioration, TCC had 3 subjects (2.2%) and WE had 21 subjects (10.8%) progressed from MCI to dementia. |
| Mortimer et al., 2012 | TCC | 50 min × 3 sessions/wk 40 wks | • WE groups showed no significant difference on neuropsychological outcomes after training.  
• The TCC group improved the Mattis Dementia Rating Scale score, TMT-A, TMT-B, the Auditory Verbal Learning Test, and verbal fluency performance.  
• TCC showed increases in **brain volume**. |
Overall, the results showed that TCC and WE both could significantly improve multiple domains of cognitive functions in community-dwelling sedentary older adults and older adults with mild cognitive impairment ($p<0.05$).

There was no significant difference in the positive training effects on verbal fluency and working memory between the TCC and WE groups.
Similar Effects of TCC and WE on Verbal Fluency

Verbal fluency ($\rho = 0.35$)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Tai Chi</th>
<th>Other exercise</th>
<th>Std. Mean Difference</th>
<th>IV, Fixed, 95% CI</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Taylor-Piliae et al 2010</td>
<td>0.8</td>
<td>4.1</td>
<td>37</td>
<td>2</td>
<td>4.7</td>
</tr>
<tr>
<td>Lam et al 2011</td>
<td>2.5</td>
<td>5.7</td>
<td>135</td>
<td>1.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Mortimer et al 2012</td>
<td>-0.38</td>
<td>4.18</td>
<td>30</td>
<td>-1.81</td>
<td>3.52</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>202</td>
<td>263</td>
<td>100.0%</td>
<td>0.09 [-0.10, 0.27]</td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: $\chi^2 = 3.61$, df = 2 ($P = 0.16$); $I^2 = 45\%$
Test for overall effect: $Z = 0.93$ ($P = 0.35$)
Similar Effects of TCC and WE on Working Memory

Forward Digit Span \((p = 1.00)\)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Tai Chi Mean</th>
<th>SD</th>
<th>Total</th>
<th>Other exercise Mean</th>
<th>SD</th>
<th>Total</th>
<th>Weight</th>
<th>Mean Difference IV, Fixed, 95% CI</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor-Piliae et al 2010</td>
<td>0.03</td>
<td>1.8</td>
<td>37</td>
<td>-0.5</td>
<td>1.6</td>
<td>39</td>
<td>15.4%</td>
<td>0.53 [-0.24, 1.30]</td>
<td>2010</td>
</tr>
<tr>
<td>Lam et al 2011</td>
<td>0.1</td>
<td>1.9</td>
<td>135</td>
<td>0</td>
<td>2.1</td>
<td>194</td>
<td>47.6%</td>
<td>0.10 [-0.34, 0.54]</td>
<td>2011</td>
</tr>
<tr>
<td>Mortimer et al 2012</td>
<td>-0.28</td>
<td>1.03</td>
<td>30</td>
<td>0.07</td>
<td>0.92</td>
<td>30</td>
<td>37.0%</td>
<td>-0.35 [-0.84, 0.14]</td>
<td>2012</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>202</td>
<td></td>
<td></td>
<td>263</td>
<td></td>
<td></td>
<td>100.0%</td>
<td>-0.00 [-0.30, 0.30]</td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Chi² = 3.96, df = 2 \((P = 0.14)\); I² = 50%
Test for overall effect: Z = 0.00 \((P = 1.00)\)

Backward Digit Span \((p = 0.14)\)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Tai Chi Mean</th>
<th>SD</th>
<th>Total</th>
<th>Other exercise Mean</th>
<th>SD</th>
<th>Total</th>
<th>Weight</th>
<th>Mean Difference IV, Fixed, 95% CI</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor-Piliae et al 2010</td>
<td>0.8</td>
<td>1.7</td>
<td>37</td>
<td>-0.7</td>
<td>1.9</td>
<td>39</td>
<td>13.2%</td>
<td>1.50 [0.69, 2.31]</td>
<td>2010</td>
</tr>
<tr>
<td>Lam et al 2011</td>
<td>0.2</td>
<td>1.7</td>
<td>135</td>
<td>0.1</td>
<td>1.6</td>
<td>194</td>
<td>65.2%</td>
<td>0.10 [-0.26, 0.46]</td>
<td>2011</td>
</tr>
<tr>
<td>Mortimer et al 2012</td>
<td>0.41</td>
<td>1.43</td>
<td>30</td>
<td>0.59</td>
<td>1.04</td>
<td>30</td>
<td>21.6%</td>
<td>-0.18 [-0.81, 0.45]</td>
<td>2012</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>202</td>
<td></td>
<td></td>
<td>263</td>
<td></td>
<td></td>
<td>100.0%</td>
<td>0.22 [-0.07, 0.52]</td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Chi² = 11.55, df = 2 \((P = 0.003)\); I² = 83%
Test for overall effect: Z = 1.49 \((P = 0.14)\)
However, TCC exercises showed greater beneficial effects on executive function than WE.
The TCC group showed greater improvement on Trail-Making Test- Part B than the WE group.

**Trail Making Test- Part A** \((p= 0.38)\)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Tai Chi Mean</th>
<th>Tai Chi SD</th>
<th>Tai Chi Total</th>
<th>Other exercise Mean</th>
<th>Other exercise SD</th>
<th>Other exercise Total</th>
<th>Mean Difference</th>
<th>Mean Difference 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lam et al 2011</td>
<td>-6.1</td>
<td>20</td>
<td>135</td>
<td>-7.3</td>
<td>23</td>
<td>194</td>
<td>1.20</td>
<td>[-3.48, 5.88]</td>
</tr>
<tr>
<td>Mortimer et al 2012</td>
<td>-11.17</td>
<td>17.47</td>
<td>30</td>
<td>2.08</td>
<td>18.08</td>
<td>30</td>
<td>-13.25</td>
<td>[-22.25, -4.25]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>-6.1</strong></td>
<td><strong>20</strong></td>
<td><strong>165</strong></td>
<td><strong>-7.3</strong></td>
<td><strong>23</strong></td>
<td><strong>194</strong></td>
<td><strong>1.87</strong></td>
<td><strong>[-6.02, 2.28]</strong></td>
</tr>
</tbody>
</table>

Heterogeneity: \(\chi^2 = 7.80, \text{df} = 1 \ (P = 0.005); I^2 = 87\%
Test for overall effect: \(Z = 0.88 \ (P = 0.38)\)

**Trail Making Test- Part B** \((p= 0.03)\)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Tai Chi Mean</th>
<th>Tai Chi SD</th>
<th>Tai Chi Total</th>
<th>Other exercise Mean</th>
<th>Other exercise SD</th>
<th>Other exercise Total</th>
<th>Mean Difference</th>
<th>Mean Difference 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lam et al 2011</td>
<td>1.7</td>
<td>62</td>
<td>135</td>
<td>12.2</td>
<td>70</td>
<td>194</td>
<td>-10.50</td>
<td>[-24.87, 3.87]</td>
</tr>
<tr>
<td>Mortimer et al 2012</td>
<td>-38.21</td>
<td>65.35</td>
<td>30</td>
<td>0.33</td>
<td>65.51</td>
<td>30</td>
<td>-38.54</td>
<td>[-71.65, -5.43]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>1.7</strong></td>
<td><strong>62</strong></td>
<td><strong>165</strong></td>
<td><strong>12.2</strong></td>
<td><strong>70</strong></td>
<td><strong>194</strong></td>
<td><strong>-14.94</strong></td>
<td><strong>[-28.12, -1.76]</strong></td>
</tr>
</tbody>
</table>

Heterogeneity: \(\chi^2 = 2.32, \text{df} = 1 \ (P = 0.13); I^2 = 57\%
Test for overall effect: \(Z = 2.22 \ (P = 0.03)\)
Both TCC & WE exercises improves cognitive functions of older adults.

A hypothetical information processing model of TCC.
Superior executive function of TCC, especially on working memory and task-switching

- TMT-A: attention and visuoperceptual abilities.
- TMT-B: cognitive flexibility and task-switching abilities.

(Sanchez-Cubillo I et al., 2009)

TCC exercises may involve more complex cognitive processes than equipment-based WE exercises.
Equipment-based WE Exercises v.s. TCC

- **Equipment-based aerobic exercises**
  - Simple repeated walking or cycling movements

- **Tai Chi Chuan**
  - Complex sequential movement patterns
  - Short forms: 12 movements
  - Long forms: 24 movements/even over 100 movements
Both WE and TCC exercises can improve verbal fluency and working memory in older adults.

Compared to WE, TCC exercises led to greater improvement in cognitive flexibility and task-switching ability in older adults.

WE and TCC exercises may potentially involve different cognitive processes.

Limitations: only 3 RCTs.

More larger clinical trials are needed.
Thank you for Your Attention