Psychological and Physiological Effects of 24-Style Taijiquan

Yunfa Liu a Kanichi Mimura b Lixin Wang b Komei Ikuta a

aGraduate School of Human Sciences, Osaka University, and bDepartment of Healthy Sports, Osaka Kyoiku University, Osaka, Japan

Introduction

The ‘super-aging society’ has recently become a critical concern, and the extension of a healthy life expectancy is an important issue. Much attention has been paid to the capacity of various sports to improve quality of life (QOL). Among them, Taijiquan (TJQ) has become an eye-catching conditioning exercise in middle-aged people in many countries. 24TJQ is a safe, low-velocity, low-impact, noncompetitive and moderate-intensity exercise [1–3]. It is highly expected to have both physiologically and psychologically beneficial effects and has therefore been considered a health-improving or life-prolonging sport.

Using the waist as the center of movement, TJQ emphasizes three essential factors, including ‘circle movements’ (body regulation), ‘shadow boxing breathing’ (breath regulation), and ‘mind concentration’ (heart regulation), it requires elegant movement, deep respiration and concentration to unify or harmonize the body with the spirit as a whole [4]. During TJQ practice, a person always imagines one opponent and utilizes every motion to respond to his/her offensive and defensive motions, which are called Taiji sense or ‘Gongfang cognition’. This is not commonly seen in other exercises or sports. Therefore, to examine the psychological effects of TJQ exercise, it is very important to consider the psychological characteristics of ‘Gongfang cognition’.

Key Words
24-style Taijiquan · Cycle ergometry · Electroencephalography Profile of Mood State

Abstract

This study was conducted to determine whether 24-style Taijiquan (24TJQ) exhibits measurable psychological and physiological effects. Twenty-two middle-aged female subjects performed 24TJQ and cycle ergometry exercises at the same intensity determined by the same heart rate during 2 exercises. Electroencephalography and Profile of Mood State (POMS) were monitored before and after 2 exercises. The responses to 24TJQ exercise were different from those to cycle ergometry exercise when the heart rate returned to the resting level: (1) α increased and θ decreased significantly in the frontal region, while θ decreased significantly in the central and occipital regions; (2) in the POMS test, an improved positive mood was found following 2 exercises, while negative mood was suppressed following 24TJQ exercise; (3) significant correlations were found between the increased α in the frontal region, the decreased θ in the central or occipital region and the vigor of the POMS test. These results suggest that 24TJQ exercise induced a resting awakening state and exhibited a relaxing effect on both mind and body.
Some studies have reported that TJQ produced beneficial psychological effects as well as physiological effects. Jin [5] reported that practice of TJQ was helpful in decreasing tension, depression, anger, fatigue, confusion and anxiety. Brown et al. [6] have also concluded that TJQ exercise was effective in promoting psychological benefits such as decreasing mood disturbance and improving general mood. Furthermore, Chen et al. [7] reported that TJQ exercise could exhibit beneficial effects, improving both the fitness index and anxiety score.

However, in most of these studies, the psychological effects of TJQ exercise were investigated with questionnaires using self-evaluation methods. There have been very few studies examining the psychological effects of TJQ exercise on brain activity, such as relaxation, using electroencephalography (EEG) [3].

In this study, middle-aged female subjects performed 24TJQ and cycle ergometry exercises at exactly the same intensity on separate occasions. The influences of exercises on the central nervous system were assessed by EEG, and the psychological effects were assessed by Profile of Mood State (POMS) tests. The results of the 24TJQ and ergometry exercises were compared, and the psychophysiological effects of 24TJQ exercise were evaluated.

Methods

Subjects

The subjects were 22 healthy middle-aged females who had practiced TJQ for 2–15 years (age: 57 ± 5.9 years). They were prohibited from ingesting alcohol, caffeine or drugs, or performing strenuous exercise within 24 h of testing, as well as having a meal within 3 h of testing. The subjects were also asked to get enough sleep the night before testing. Each subject provided informed consent regarding the procedures involved in the study. No details concerning the purpose of the experiment were given to subjects until after completion of all testing.

Determination of Oxygen Uptake and Maximal Oxygen Uptake during Incremental Ergometry Exercise

To investigate the level of exercise before testing, oxygen uptake, maximal oxygen uptake and heart rate (HR) were determined during an incremental cycle ergometry exercise. All subjects pedaled at a constant speed of 60 rpm and the loads were increased to 1.0, 1.5 and 2.0 kp for 4 min, respectively; the loads were further increased by 0.25 kp/min until the subject breathed with difficulty or felt intolerably tired. Oxygen uptake was determined continuously during exercise and maximal oxygen uptake was calculated. Expired air was analyzed using respiratory metabolism examination equipment (2900, Sensor Medics Co., Japan) with a breath-by-breath system.

Using the data of oxygen uptake and HR during incremental cycle ergometry exercise, a regression line between 2 parameters was made for each subject. Using the regression line, the mean TJQ exercise intensity (%VO₂ max) was calculated from the mean HR during TJQ exercise, and cycling ergometry exercise was performed smoothly with the same intensity as 24TJQ exercise.

Comparative Test between 24TJQ and Ergometry Exercises

Procedures

Tests were carried out in two sessions. 24TJQ exercise and POMS tests were conducted first, and ergometry exercise (Compuronic aerobike 75 XL, Combi Corp., Tokyo, Japan) and POMS tests 7 days later. Many researchers [8, 9] have indicated that EEG can exhibit diurnal variation. EEG was determined at a similar measuring time for each exercise.

Experimental Protocols

EEG recording was conducted all with eyes closed during a 3-min rest period prior to exercise (pre), during 3 min immediately after exercises (post1) and 3 min after returning to the rest HR (post2). An average of 8 min (8.3 ± 0.7) from the end of post1 was spent to start post2 measurements.

Measurement Method

EEG and HR data were simultaneously obtained using an EEG Telemeter System WEE-6112 (Nihon Kohden). The HR was recorded via two 10-mm AgCl disc electrodes located at the left breast.

EEG Measurement and Data Processing

EEG recordings were obtained from all subjects before and after 24TJQ and ergometry exercises. Ten-millimeter Ag-AgCl disc electrodes (supply code H503A, model NE-113A, Nihon Kohden) were attached bilaterally to the scalp and the earlobes, according to the International 10-20 System procedures. Electrodes were filled with electroconductive cream (supply code F510, model Z-401CE, Nihon Kohden) and placed at the following places: Fp1, Fp2, C3, C4, O1 and O2. These electrode sites were selected to record the whole brain electroactivity from the frontal to the occipital regions. Each bipolar lead was referred to the linked earlobes. The forehead was used for grounding. Three electrooculographic leads (FP1-A1, PG1-A1 for vertical and PG1-PG2 for horizontal eye movements) were added for artifact monitoring. The electrode impedance was kept below 5 kΩ throughout the recording session. Light gauze pads were placed over the eyelids to reduce blink artifacts.

For each session, a 50-μV sine wave provided by EEG machine was passed through all channels amplifiers, digitized on-line, and submitted to a fast Fourier transform. The root-mean-square of total power was used to calculate a gain correction factor to be applied to each channel to ensure interchannel comparability (within ± 0.5 μV). A null calibration for zero level determination was also performed by shorting the input channels to the ground before the analog-to-digital (A/D) converter. In this way, any DC component would have been detected and corrected, although this was never the case.

The EEG signal was amplified 20,000 times using a Nihon Kohden model AE-600A with band-pass filter settings of 1.3–35 Hz and a 50-Hz notch filter.

In each 3-min recording session, subjects were instructed to relax but not to sleep, and to avoid making movements during the recording. Compliance to the instructions was monitored through-
out the session. No drowsiness was noticed during the EEG recordings (no occipital α dropout and fragmentation appeared, with a shift to the anterior regions, in conjunction with background slowing).

Visual examination of the EEG recordings was performed to identify and then exclude all the EEG epochs with artifacts and/or the single leads with local artifacts (e.g. muscle activity, blinks, electrode artifacts). Only EEG recordings with at least 25 artifact-free 5-second epochs were included in this study.

The EEG signal was digitized with a sampling frequency of 256 Hz; it was then submitted to a fast Fourier transform for offline using Neurofax software (EEG-1000, v03-01, Nihon Kohden).

The EEG data for 3 min before and after exercise were classified into θ-wave (4–8 Hz), α-wave (8–13 Hz) and β-wave (13–30 Hz). Preliminary descriptive analysis revealed that none of the evaluated quantitative EEG indices show a normal distribution. To obtain a better approximation to this distribution, the relative power was submitted to a log transformation. The log of the relative power (LRP) [10].

**POMS Test**

The POMS test has been generally used to examine mood changes following exercise [11, 12]. In this study, changes in the mood of each subject after exercise were investigated, 10 min before and 30 min after 24TJQ or ergometry exercises using the POMS test in Japanese [13].

The POMS test consisted of 65 questions about the mood state from 1 week before to the present. The subjects selected raw scores, which were graded into five levels (0, 1, 2, 3, 4). These raw scores were added up to categorize six subscales: tension and anxiety (T-A), depression and dejection (D), anger and hostility (A-H), vigor (V), fatigue (F) and confusion (C). To conduct statistical analysis using these parameters, the raw scores for the 6 subscales were converted into T scores, according to the POMS manuals [13].

**Statistical Analyses**

The time effects of LRP, αLRP and βLRP at pre, post1 and post2 in 3 regions (Fp, C and O) were analyzed using one-way ANOVA. When a significant difference was found, the Fisher minimum significant test was conducted.

The POMS T scores before and after 24TJQ and ergometry exercises were compared using a paired Student t test.

To examine the correlation between EEG changes and POMS scores, the differences of θLRP, αLRP and βLRP between post2 and pre (post2 – pre) were plotted against the differences of POMS scores taken before and after exercises. The correlation between the 2 differences was analyzed using SPSS for Windows 10.07. p values < 0.05 were considered significant (two tailed).

**Results**

**HR and Respiratory Rate**

Table 1 shows HR (mean ± SD) before, during and after 24TJQ and cycle ergometry exercises in 22 subjects. The ergometry exercise intensity for each subject corresponded to the intensity of the 24TJQ exercise in terms of HR during exercises and no significant differences were found between the 2 exercises.

**Electroencephalography Changes of αLRP in the Frontal, Central and Occipital Regions (table 2)**

Significant time effects of LRP [F(2, 63) = 4.50, p < 0.05] in the frontal and central regions were recognized by one-way ANOVA test. The Fisher minimum significance tests revealed that αLRP in the frontal region was significantly greater at post2 than at pre and post1 (p < 0.05, for both) and αLRP in the central region was significantly greater at post2 than at pre and post1 (p < 0.05 for both). But no significant time effect for αLRP was recognized in the occipital region after 24TJQ exercise. In addition, no any significant difference of αLRP was found in all 3 regions after ergometry exercise.

**Changes of θLRP in the Frontal, Central and Occipital Regions (table 3)**

The time effects of θLRP in the frontal [F(2, 63) = 6.81, p < 0.01], central [F(2, 63) = 6.88, p < 0.01] and occipital

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<thead>
<tr>
<th>Table 1. Means and SD of heart rate by condition (bpm; n = 22)</th>
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<td>Pre</td>
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<th>Table 2. Means and SD of the αLRP over the frontal, central and occipital regions and results of ANOVA on LRP data by condition (n = 22)</th>
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<td>24TJQ</td>
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<td>Post1</td>
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<td>Post2</td>
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<td>Ergometry</td>
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<td>Post2</td>
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* p < 0.05.
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Fig. 1. POMS score of the six subscales on 24TJQ and cycle ergometry. * p < 0.05; ** p < 0.01.

Table 3. Means and SD of the αLRP over the frontal, central and occipital regions and results of ANOVA on LRP data by condition (n = 22)

<table>
<thead>
<tr>
<th></th>
<th>Frontal</th>
<th>Central</th>
<th>Occipital</th>
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<tbody>
<tr>
<td>24TJQ</td>
<td></td>
<td></td>
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<tr>
<td>Pre</td>
<td>−1.14±0.48</td>
<td>−1.59±0.39</td>
<td>−2.07±0.48</td>
</tr>
</tbody>
</table>
| Post1 | −1.13±0.68  | **−1.64±0.40** | **−2.17±0.51** | *  
| Post2 | −1.68±0.54  | **−2.01±0.45** | **−2.42±0.49** |  

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<tr>
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<td></td>
<td></td>
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<tr>
<td>Pre</td>
<td>−1.28±0.47</td>
<td>−1.53±0.33</td>
<td>−2.01±0.35</td>
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<tr>
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<td>−1.25±0.47</td>
<td>−1.64±0.34</td>
<td>−2.12±0.38</td>
</tr>
<tr>
<td>Post2</td>
<td>−1.39±0.40</td>
<td>−1.62±0.34</td>
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</tbody>
</table>

* p < 0.05; ** p < 0.01.

regions [F(2, 63) = 3.81, p < 0.05] were all significantly recognized. The post-hoc test showed that αLRP in the frontal region was greater at post2 than at pre (p < 0.01) and at post1 (p < 0.01); αLRP in the central region was greater at post2 than at pre (p < 0.01) and at post1 (p < 0.01). αLRP in the occipital region was greater at post2 than at pre (p < 0.05). On the other hand, no significant difference of αLRP was found in all 3 regions after ergometry exercise.

Changes of βLRP in the Frontal, Central and Occipital Regions (table 4)

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<td>Post1</td>
<td>−1.41±0.50</td>
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<td>Post2</td>
<td>−1.50±0.49</td>
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<tbody>
<tr>
<td>Ergometry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>−1.30±0.66</td>
<td>−1.23±0.64</td>
<td>−1.54±0.67</td>
</tr>
<tr>
<td>Post1</td>
<td>−1.44±0.60</td>
<td>−1.31±0.65</td>
<td>−1.61±0.64</td>
</tr>
<tr>
<td>Post2</td>
<td>−1.44±0.69</td>
<td>−1.36±0.60</td>
<td>−1.62±0.63</td>
</tr>
</tbody>
</table>

POMS Test

Figure 1 shows the mean T scores in the six subscales of the POMS test, before and after 24TJQ and ergometry exercises. The positive mood score, which is indicated by V, increased significantly following 24TJQ (p < 0.01) and ergometry exercises (p < 0.05); the negative mood score showed a significant decrease [T-A (p < 0.01), D (p < 0.01), A-H (p < 0.01), F (p < 0.01) and C (p < 0.01)] for 24TJQ exercise, but no significant changes occurred following the ergometry exercise.

Relationship between EEG Change and POMS T Scores Change after Exercises

As shown in figure 2, a significant positive correlation was found between increased αLRP in the frontal region
and increased V score of the POMS test ($r = 0.675; p < 0.001$), and significant negative correlations were found between decreased $\theta$LRP in the central ($r = -0.728; p < 0.001$) and increased V score of the POMS test after 24TJQ exercise. However, in ergometry exercise, no significant correlation was found between the change of $\alpha$LRP or $\theta$LRP in any region and the increased V score of the POMS test.

For the other 5 subcomponents, except the V score, no significant correlations were found between the change of $\alpha$LRP or $\theta$LRP in any region and the 5 respective subcomponents of the POMS test. No correlations were found between the change of $\beta$LRP and the change of POMS scores after 24TJQ and ergometry exercises.

**Discussion**

The results of this study showed that in the recovery period of 24TJQ exercise after HR returned to the resting level (post2): (1) $\alpha$LRP increased both in the frontal and central regions, and $\theta$LRP decreased in all 3 regions; (2) the negative components of the POMS test decreased in the 24TJQ exercise; (3) the increased $\alpha$LRP in the frontal region and the decreased $\theta$LRP in the central or occipital regions significantly correlated with the increased V score of the POMS test.

The significant increase in $\alpha$LRP in the frontal/central regions and the significant decreases in $\theta$LRP in the central or occipital regions did not appear until the post2 after 24TJQ exercise. This suggested that the cerebral cortex activity did not decrease or become calm immediately after 24TJQ exercise (in the post1), but did become calm in the post2, which resulted in a relaxing effect on the mind and body [14]. Although occipital dominance of $\alpha$-wave is the ordinary pattern in normal psychological conditions, studies [15–17] have revealed that the wave will spread to the central and frontal regions, or appear simultaneously in the occipital region. We have also reported that $\alpha$-wave in the skilled showed a central dominance during and after 24TJQ exercise instead of ordinary occipital dominance [3]. The distribution shift in the present study suggests that highly concentrated practice of 24TJQ might shift $\alpha$-wave from the ordinary occipital to the central or frontal regions of the brain, but a certain degree of time lag is needed. This result means that 24TJQ is useful to improve concentration capacity. This study was the first to confirm the beneficial physiological effects with objective EEG parameters, and suggested that 24TJQ exercise is a suitable health-conditioning exercise for middle-aged people.

The results of the POMS test indicated an improved positive mood and a suppressed negative mood. Additionally, the $\alpha$LRP change in the frontal region significantly correlated with POMS score change (fig. 2a), while the decrease in $\theta$LRP in the central and occipital regions negatively correlated with the increase in the V score (fig. 2b, c). These results suggested that the EEG changes, including $\alpha$LRP increase in the frontal regions and $\theta$LRP decrease in the central or occipital region, were associated with the attainment of psychological relaxation, and psychological V was enhanced after passing through the 20-min relaxation state. Our previous study showed that, after 24TJQ exercise, the $\alpha$LRP increased and psychological relaxation appeared [3], but this study indicated that the more the $\alpha$LRP increased or the $\theta$LRP decreased,
the higher the psychological relaxation level became. Moreover, this study provided objective data to show the increase in psychological V following the appearance of psychological relaxation after 24TJQ exercise.

In the ergometry exercise, there were no significant changes in αLRP, βLRP and θLRP as after 24TJQ exercise. These results demonstrated that the ergometry exercise exhibited little effect on EEG, both psychologically and physiologically. However, as indicated by the POMS scores in figure 1, the V score of the POMS test increased significantly (p < 0.05), similar to that in the 24TJQ exercise. These data suggested that even though the ergometry exercise, which was different from the TJQ exercise, did not exhibit any psychologically relaxing effects after exercise, it did elicit some psychological refreshment shown as the increase in V.

The α-wave increase after 24TJQ exercise corresponded well to the results of some previous studies, which reported an α-wave increase after aquatic aerobics and walking exercises [14, 18, 19]. However, no changes in α-wave were observed after ergometry exercise. These results suggested that 24TJQ exercise exhibited a stronger tranquilizing effect on the cerebral cortex activity than ergometry exercise even with the same exercise intensity and duration. Because increased α-wave has been considered to reflect sedated cerebral cortex activity as a consequence of reduced physiological cerebral activity after exercise [20], this result suggested that cerebral cortex activity was suppressed to a greater degree after 24TJQ exercise than ergometry exercise. In TJQ exercise, a person utilizes a special cognitive component of ‘Gongfang cognition’ during participation, but after the completion of TJQ, ‘Gongfang cognition’ disappears immediately and cerebral cortex activity becomes calm, leading to reduced cerebral physiological activity.

It has been reported that aerobic exercises, including exercises on land [21, 22] and swimming [18], exhibit beneficial effects regarding anxiety, dysphoria and excessive tension. In this study, it was also confirmed with the αLRP determination and the POMS test that 24TJQ exercise exhibited a significant positive effect on mood. In the ergometry exercise, no correlation was significant regarding changes of the POMS test and EEG after exercise. However, in the TJQ exercise, significant correlations were observed in the V score change of the POMS test and αLRP increase or θLRP decrease after 24TJQ exercise (post2); the increased α wave and the decreased θ-wave after 24TJQ exercise were significantly associated with the increase in V. We considered that the disappearance of ‘Gongfang cognition’ after the completion of 24TJQ exercise resulted in the liberation from psychological pressure, which resulted in the increase in both α-wave and V. Reduced depression and fatigue after 24TJQ exercise might be related to the decrease in θ-wave, which is in agreement with the description of Gale and Edwards [23].

Shiro et al. [18] have reported that a continuous, physiologically excited state after exercise suppressed the appearance of low-frequency EEG (θ-wave). In this study, after 24TJQ exercise (post2), no continuously increasing or physiologically excited state was observed, θ-wave decreased with stable and low HR, even though we could not confirm the correlation between the decrease in θ-wave and the individual subcomponent of POMS test except V. But a previous study [20] demonstrated that the decreased θ-wave resulted in the reduction of depression and fatigue, which could be brought on by decreased sympathetic action on the hypothalamus.

It is known that with aging, both physical and central nervous system activity decrease. Research on how to delay or reverse aging symptoms such as impairment of memory, cognition and information processing which result in a decline of QOL, both physiologically and psychologically, is an urgent challenge. Dynamic exercise of the whole body might improve the general or local blood influx to the brain and regulate the secretion of some important chemical substances, which could affect a person’s psychological status [24, 25]. This study also suggested that, as a kind of whole-body exercise with the utilization of ‘Gongfang cognition’, 24TJQ exercise could increase cerebral activity. This may well vitalize brain function and delay the aging process.

In conclusion, this study suggests that as a moderate-intensity exercise for middle-aged people, 24TJQ exercise results in beneficial psychological and physiological effects, which was confirmed by the results of both psychological testing and EEG. After 24TJQ exercise, the increased α-wave and the decreased θ-wave were associated with the increase in V mood score. These effects are likely to improve the QOL of middle-aged people.
References


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