Simulation Study of 24–Form Tai Chi Typical Movements Factors Based on Computer Analysis

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Abstract. Objective: In order to provide the scientific conduction of Tai Chi practitioners. **Method:** Taking the neuromuscular control of Tai Chi exercise as the starting point, by infrared capture system and Any Body human modeling simulation system, compared ability of professional group and preliminary group. **Results:** (1) Tai Chi practice is positive on balance, proprioception and neuromuscular control. (2) In professional group and preliminary group, the hip abduction angular velocity of Parting the wild horse's mane, the ankle plantar flexion angle of Brush knee and twist step, the hip flexion angle of Grasp the bird's tail, the knee flexion angular velocity of Single whip and the hip rotation angular velocity of Apparent close up were significantly different ($P < 0.05$). (3) The hip flexion moment of Parting the wild horse's mane, the ankle plantar flexion moment of Flash the arm were significantly different ($P < 0.05$). (4) The musculi adductor magnus muscle strength of Parting the wild horse's mane and Apparent close up, iliopsoas muscle strength of Brush knee and twist step, musculi obturator externus muscle strength of Grasp the bird's tailwere significantly different ($P < 0.05$). **Conclusions:** (1) The exercise of Tai Chi intensity was moderate, there was a certain effect on the lateral balance. The practitioners adjust themselves and maintain body posture stable while maintaining the dynamic balance process. (2) Dynamic optimization problem drives muscle activation with human segmental motion and ground reaction force, optimizes the kinematic model parameters of joints, generates data to track dynamic optimization, and simulates the muscle excitation mode.

Keywords: Computer analysis · AnyBody · Simulation

1 Introduction

Tai Chi and other medium intensity aerobic exercise not only makes the central nervous function plastic change [1], but also has positive effect on physical health, health care, on the basis of exercise, can improve the accuracy of human movements, and improve posture stability, reduce the risk of fall [2]. At present, the research on the characteristics

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Table 1. Basic information of subjects

group	Number of people (n)	Age (year)	Height (cm)	Weight (kg)	BMI
Professional group	30	20.37 ± 0.82	175.98 ± 5.32	68.67 ± 10.41	22.17 ± 2.32
Control group	30	20.62 ± 1.07	176.32 ± 4.86	70.15 ± 11.63	21.38 ± 3.24
	60	20.45 ± 0.95	176.15 ± 5.09	69.41 ± 11.02	21.78 ± 2.78

of Tai Chi mainly focus on balance [3], and there are few studies on the changes of plantar pressure, movement speed, joint angle and muscle strength. This study aims to provide the theoretical basis and reference for the scientific movement of Tai Chi practitioners.

2 Study Subjects and Methods

2.1 Study Subjects

A total of 66 subjects were selected, randomly divided into professional group and control group. Those who withdrew for physical reasons or other reasons and cannot complete the final test were excluded. 30 cases in the professional group and 30 cases in the control group were included in the analysis. There was no significant difference in height, weight, BMI [body mass index (BMI) = body weight (kg)/height ^{2} (m^2)] ($P > 0.05$), shown in Table 1.

2.2 Method

2.2.1 Kinematic Test Method

Before the test, subjects maintained intrinsic physical condition and health, while measuring the basic indicators such as hip width, hip depth, knee width and ankle width. Which analyzes kinematic parameters, collects kinematic data, and processes kinematic parameters with AnyBody 7.1.2 software.

2.2.2 Kinetic Test Method

The calculation results show that the degree of motion of the maximum muscle strength of the lower limb muscles, such as soleus and medial femorus muscles, etc. The lower limb musculo-skeletal model was shown in Fig. 1 [4].

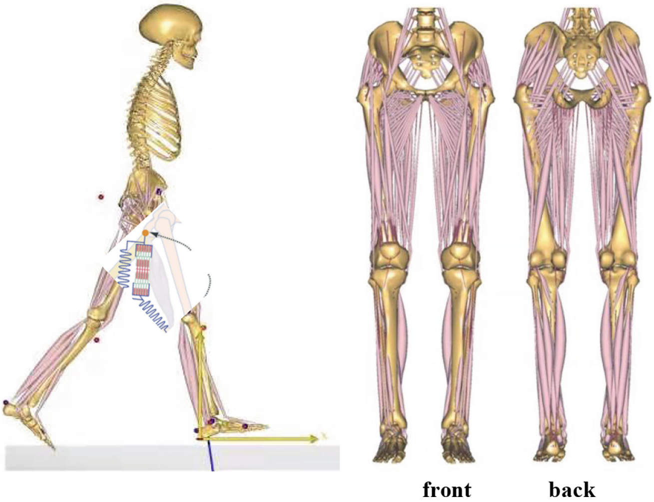

Fig. 1. Lower extremity musculoskeletal model [4]

2.2.3 AnyBody Software Modeling Principle

A static algorithm for reverse dynamics of AnyBody Modeling System:

$\min G(F^M)$

$G(F^M) = \max(A^M{}_i) = \max(F^M{}_i/N_i)$

$CF^M = R, 0 \leq F^M{}_i \leq N_i, i = 1, 2, 3,\ldots,n^M$

F^M: muscle force; N_i: muscle intensity; $A^M{}_i$: muscle activity (muscle force / intensity); C: system matrix; R: ground reaction force; n^M: muscle number.

2.3 Statistical Analysis

The lunge was the common effect of the muscles such as the foot, ankle joint, knee joint and hip joint. In this study, the characteristics when the heel touches the ground to the toe off the ground were selected as the research stage. Descriptive statistics were performed using IBM SPSS Statistics 20.0 (SPSS Science, Chicago, Illinois). With the independent sample T-test to compare the difference in indicators, all tests were two-sided, the significance level was $\alpha = 0.05$.

3 Results

3.1 Kinematic Test Results

In Table 2, in different groups, the hip abduction angular velocity of Parting the wild horse's mane, the ankle plantar flexion angle of Brush knee and twist step, the hip flexion angle of Grasp the bird's tail, the knee flexion angular velocity of Single whip and the hip rotation angular velocity of Apparent close up were significantly different ($P < 0.05$).

Table 2. Results of the kinematic tests

kinematic results	groups	Parting the wild horse's mane	Brush knee and twist step	Grasp the bird's tail	Single whip	Flash the arm	Apparent close up
hip abduction angle°	professional group	14.33 ± 3.62	5.73 ± 0.68	10.89 ± 1.44	17.75 ± 2.08	9.74 ± 1.51	10.89 ± 2.15
	preliminary group	14.27 ± 3.80	5.69 ± 0.71	10.37 ± 1.20	17.06 ± 3.24	9.63 ± 1.82	10.63 ± 1.77
hip flexion angle°	professional group	27.19 ± 8.05	34.89 ± 3.56	9.16 ± 2.08*	6.88 ± 1.27	14.71 ± 3.24	12.61 ± 2.38
	preliminary group	26.45 ± 8.23	33.25 ± 4.37	8.01 ± 2.34	6.54 ± 1.40	14.39 ± 2.08	12.45 ± 3.42
hip rotation angle°	professional group	5.16 ± 1.29	8.61 ± 1.25	9.17 ± 1.30	16.04 ± 2.85	8.59 ± 1.27	6.30 ± 1.59
	preliminary group	5.05 ± 0.83	8.22 ± 1.34	9.03 ± 1.25	15.79 ± 3.16	8.43 ± 1.18	6.18 ± 2.02
knee flexion angle°	professional group	34.89 ± 2.41	36.04 ± 2.91	38.34 ± 6.09	33.75 ± 3.84	42.61 ± 3.40	38.97 ± 6.08
	preliminary group	33.93 ± 2.15	35.69 ± 3.20	39.48 ± 5.16	32.30 ± 4.51	42.78 ± 3.29	39.25 ± 4.23
ankle plantar flexion angle°	professional group	16.88 ± 1.36	38.20 ± 6.47*	29.80 ± 3.26	16.62 ± 3.09	44.69 ± 5.87	30.37 ± 3.18
	preliminary group	15.54 ± 1.29	34.65 ± 4.28	28.47 ± 3.15	17.09 ± 4.33	43.21 ± 3.64	30.26 ± 4.82
hip abduction angle velocity (rad/s)	professional group	0.65 ± 0.06*	0.28 ± 0.06	0.61 ± 0.17	0.43 ± 0.11	0.44 ± 0.07	0.31 ± 0.06
	preliminary group	0.61 ± 0.08	0.29 ± 0.05	0.64 ± 0.13	0.46 ± 0.12	0.45 ± 0.08	0.33 ± 0.07
hip flexion angle velocity (rad/s)	professional group	0.37 ± 0.11	0.49 ± 0.08	0.24 ± 0.05	0.31 ± 0.09	0.05 ± 0.02	0.08 ± 0.02
	preliminary group	0.39 ± 0.12	0.51 ± 0.07	0.25 ± 0.07	0.30 ± 0.10	0.05 ± 0.03	0.08 ± 0.03

(*continued*)

Table 2. (*continued*)

kinematic results	groups	Parting the wild horse's mane	Brush knee and twist step	Grasp the bird's tail	Single whip	Flash the arm	Apparent close up
hip rotation angular velocity (rad/s)	professional group	0.69 ± 0.14	0.78 ± 0.24	0.22 ± 0.06	0.42 ± 0.13	0.28 ± 0.06	0.26 ± 0.04*
	preliminary group	0.71 ± 0.18	0.75 ± 0.21	0.20 ± 0.05	0.41 ± 0.15	0.32 ± 0.09	0.23 ± 0.05
knee flexion angle velocity (rad/s)	professional group	0.63 ± 0.12	1.12 ± 0.34	0.57 ± 0.14	0.67 ± 0.12*	0.69 ± 0.14	0.51 ± 0.06
	preliminary group	0.65 ± 0.14	1.20 ± 0.35	0.59 ± 0.12	0.60 ± 0.14	0.73 ± 0.15	0.54 ± 0.07
ankle plantar flexion angle velocity (rad/s)	professional group	0.11 ± 0.03	0.53 ± 0.11	0.39 ± 0.05	0.41 ± 0.09	0.25 ± 0.07	0.22 ± 0.04
	preliminary group	0.12 ± 0.05	0.54 ± 0.16	0.41 ± 0.07	0.40 ± 0.08	0.24 ± 0.06	0.23 ± 0.05

Note: * There are significant differences between the professional group and the preliminary group ($P < 0.05$)

Table 3. Results of the joint moment (unit: Nm/kg)

kinetic results	groups	Parting the wild horse's mane	Brush knee and twist step	Grasp the bird's tail	Single whip	Flash the arm	Apparent close up
hip abduction moment	professional group	0.70 ± 0.15	0.39 ± 0.05	0.68 ± 0.15	0.35 ± 0.06	0.27 ± 0.05	0.67 ± 0.09
	preliminary group	0.61 ± 0.14	0.36 ± 0.07	0.59 ± 0.17	0.32 ± 0.04	0.24 ± 0.06	0.61 ± 0.12
hip flexion moment	professional group	0.29 ± 0.06*	0.21 ± 0.04	0.51 ± 0.08	0.20 ± 0.08	0.57 ± 0.14	0.65 ± 0.13
	preliminary group	0.25 ± 0.08	0.18 ± 0.07	0.47 ± 0.06	0.16 ± 0.05	0.50 ± 0.12	0.57 ± 0.09
hip rotation moment	professional group	0.16 ± 0.02	0.08 ± 0.02	0.05 ± 0.01	0.12 ± 0.04	0.05 ± 0.02	0.05 ± 0.02
	preliminary group	0.15 ± 0.03	0.07 ± 0.02	0.05 ± 0.03	0.11 ± 0.02	0.05 ± 0.03	0.05 ± 0.03
knee flexion moment	professional group	0.66 ± 0.12	0.35 ± 0.06	1.02 ± 0.25	0.59 ± 0.07	0.30 ± 0.07	0.95 ± 0.16
	preliminary group	0.58 ± 0.15	0.30 ± 0.07	0.97 ± 0.21	0.55 ± 0.06	0.28 ± 0.06	0.87 ± 0.14
ankle plantar flexion moment	professional group	0.66 ± 0.05	0.71 ± 0.08	0.51 ± 0.08	0.44 ± 0.08	0.49 ± 0.12*	0.93 ± 0.12
	preliminary group	0.62 ± 0.09	0.64 ± 0.15	0.50 ± 0.12	0.39 ± 0.10	0.43 ± 0.08	0.89 ± 0.13

3.2 Kinetic Test Results

In Table 3, in different groups, the hip flexion moment of parting the wild horse's mane, the ankle plantar flexion moment of Flash the arm were significantly different ($P < 0.05$).

3.3 Results of the Simulated Muscle Strength

In Table 4, in different groups, musculi adductor magnus muscle strength of Parting the wild horse's mane and Apparent close up, iliopsoas muscle strength of Brush knee and twist step, musculi obturator externus muscle strength of Grasp the bird's tail were significantly different ($P < 0.05$).

Table 4. Results of the simulated muscle strength (N/BW)

muscle strength results	groups	Parting the wild horse's mane	Brush knee and twist step	Grasp the bird's tail	Single whip	Flash the arm	Apparent close up
iliacus	professional group	0.115 ± 0.024*	0.124 ± 0.017	0.129 ± 0.032	0.047 ± 0.012	0.049 ± 0.008	0.053 ± 0.009
	preliminary group	0.102 ± 0.013	0.128 ± 0.053	0.125 ± 0.047	0.045 ± 0.014	0.047 ± 0.012	0.048 ± 0.013
iliopsoas	professional group	0.213 ± 0.005	0.234 ± 0.058*	0.247 ± 0.006	0.059 ± 0.011	0.062 ± 0.015	0.067 ± 0.019
	preliminary group	0.215 ± 0.014	0.209 ± 0.012	0.243 ± 0.013	0.055 ± 0.013	0.067 ± 0.013	0.068 ± 0.013
gluteus minimus	professional group	0.103 ± 0.041	0.103 ± 0.067	0.115 ± 0.071	0.124 ± 0.026	0.125 ± 0.034	0.127 ± 0.062
	preliminary group	0.102 ± 0.043	0.098 ± 0.054	0.105 ± 0.047	0.125 ± 0.014	0.127 ± 0.016	0.118 ± 0.019
glutaeus medius	professional group	1.253 ± 0.034	1.256 ± 0.235	1.275 ± 0.028	0.037 ± 0.014	0.313 ± 0.012	0.338 ± 0.013
	preliminary group	1.068 ± 0.027	1.139 ± 0.142	1.243 ± 0.016	0.038 ± 0.012	0.341 ± 0.009	0.346 ± 0.011
glutaeus maximus	professional group	0.156 ± 0.012	0.155 ± 0.024	0.152 ± 0.022	0.153 ± 0.021	0.151 ± 0.034	0.159 ± 0.031
	preliminary group	0.153 ± 0.025	0.151 ± 0.033	0.150 ± 0.031	0.158 ± 0.014	0.154 ± 0.013*	0.167 ± 0.018
piriformis	professional group	0.135 ± 0.026	0.137 ± 0.018	0.141 ± 0.024	0.133 ± 0.021	0.034 ± 0.017	0.140 ± 0.022
	preliminary group	0.140 ± 0.039	0.139 ± 0.012	0.137 ± 0.018	0.132 ± 0.016	0.032 ± 0.008	0.131 ± 0.019
musculi obturator externus	professional group	0.175 ± 0.035	0.177 ± 0.032	0.181 ± 0.034*	0.030 ± 0.008	0.034 ± 0.013	0.039 ± 0.012
	preliminary group	0.177 ± 0.028	0.175 ± 0.036	0.165 ± 0.027	0.025 ± 0.006	0.029 ± 0.008	0.040 ± 0.008

(continued)

Table 4. (*continued*)

muscle strength results	groups	Parting the wild horse's mane	Brush knee and twist step	Grasp the bird's tail	Single whip	Flash the arm	Apparent close up
musculi obturator internus	professional group	0.254 ± 0.016	0.158 ± 0.024	0.264 ± 0.018	0.251 ± 0.012	0.253 ± 0.029	0.136 ± 0.017
	preliminary group	0.260 ± 0.013	0.159 ± 0.021	0.269 ± 0.025	0.253 ± 0.014	0.245 ± 0.068	0.139 ± 0.015
musculi adductor longus	professional group	0.135 ± 0.023	0.133 ± 0.015	0.132 ± 0.021	0.131 ± 0.019	0.221 ± 0.036	0.243 ± 0.019
	preliminary group	0.134 ± 0.018	0.138 ± 0.012	0.133 ± 0.027	0.135 ± 0.016	0.236 ± 0.043	0.250 ± 0.012
musculi adductor magnus	professional group	0.243 ± 0.056*	0.241 ± 0.028	0.239 ± 0.025	0.126 ± 0.017	0.129 ± 0.021	0.251 ± 0.034*
	preliminary group	0.217 ± 0.035	0.225 ± 0.031	0.223 ± 0.018	0.125 ± 0.018	0.134 ± 0.019	0.226 ± 0.058

4 Discussion

This study focus on the national major strategic development direction, and healthy China strategy, focus on martial arts and traditional sports inheritance and development, martial arts and national traditional sports into the campus, traditional health work in promoting the national fitness, the key technology and promotion, martial arts and the development of traditional sports.

Tai Chi practice emphasis on both shape and spirit, inside and outside, the movement of slow pace, attaches great importance to the control of the body movements, practitioners loose waist heavy hip, outside body guidance, most of the research in the elderly, balance disorders and other sports, movement biomechanical characteristics analysis of Tai Chi research less, this study the comparative analysis of kinematics, dynamics, reveals Tai Chi to improve the influence of muscle strength. Tai Chi practitioners pay attention to flexible transformation footwork [5]. Tsang et al. [6] found that further tilt had better control over their tilt trajectory without losing their stability. Tsang et al. [6] found that Tai Chi practitioners were significantly better at proprioception, visual and vestibular perception, with no significant difference between Tai Chi practitioners and young healthy participants. Hallisy et al. [2] found that elderly 16 weeks of Tai Chi practice can prevent falls. Each movement of Tai Chi was beneficial to body.

During the process of Tai Chi, people constantly bend knees and loosen hips, with the characteristics of deep knee flexion and wide step length, maintaining stability in the single and double foot conversion support, through lower limb joint continuously flexion stretch, with slow stable posture by a position to other position, exercise muscle coordination work ability, long-term single and double foot support practice way fully exercise the body in various directions of the stability [7]. During the process of the lunge, Parting the wild horse's mane divides the legs before and back, the front foot was a big step forward, the front solid leg and the back empty leg, the upper body was forward, the shoulders were vertical to the front leg. During the process of the Brush knee and twist step, the hip joint bends, and the center of gravity should not be too high to avoid left and right instability. The peak pressure of the metatarsal and toes of the professional group is large, which is conducive to improving the muscle strength in the process of knee bending and hip rotation.

During the process of Brush knee and twist step, the iliotibial bundle in the outer thigh contracts, and the flexion and extension of the hip joint maintains a stable center of gravity. The tibialis anterior muscles straighten the knee joint, in the swing phase, the gastrocnemius muscles make the knee joint flexion, the gastrocnemius muscles and tibialis anterior muscles contract together to complete the activity. During the process of Tai Chi, all directions are complex and changeable, the abduction and abduction of the knee joint are constantly changing, and the triceps of the leg are powerful. Therefore, it is particularly important to study the influence of Tai Chi on the lower limb muscle strength. In this study, Difference minimization was achieved by the AnyBody model marker traces and motion capture marker traces. After kinematic optimization, a force-related kinetic analysis was performed and muscle strength was determined using a numerical optimization procedure using a polynomial cubic muscle recruitment standard. The reverse dynamics of skeletal muscle is based through three calculation processes: the joint angle and muscle force distribution are derived from the high-order recurrence derivative formula; the uncertainty of multiple contacts between human and environment, and the force and torque are distributed to each contact point; the segmentation ratio of the joint angle control point, muscle force control point, node vector and contact point.

5 Conclusions

(1) The exercise of Tai Chi intensity was moderate, both coherent and round, and has a certain effect on the lateral balance. The practitioners adjust themselves and maintain body posture stable while maintaining the dynamic balance process.
(2) Dynamic optimization problem drives muscle activation with human segmental motion and ground reaction force, optimizes the kinematic model parameters of joints, generates data to track dynamic optimization, and simulates the muscle excitation mode.

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