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Research Article

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Taijiquan needle at sea bottom motion physiological parameters and knee sports injury correlation analysis

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ABSTRACT

Through researching on Taijiquan Needle at Sea Bottom motion process human postures status, it provides space image basis for knee joint force analysis and knee joint relative segments movements' dynamical analysis. Apply rigid mechanics theory and Lagrange's dynamical equations; analyze knee joint force status and human lower limbs motions dynamical equations that provides theoretical basis for knee joint injury causes. Utilize digital camera and three dimensional force platform system and other equipment, collecting habitual position posture, stand position posture and right knee minimum joint angle posture these three postures knee joint biomechanical parameters, get that human stand position and habitual postures right knee joint muscle torques have very significant differences, and habitual position muscle torque is 1.07 to 2.06 times higher than that in stand position. When human in habitual posture, its knee joint stability mainly relies on quadriceps femoris and ligament to maintain; and knee joint get flexion in habitual position would let quadriceps femoris excessive stretch that easier to wear it down causing patellar ligament also prone to get injured .Under habitual postures and right knee minimum joint angle postures such two postures, when joint angle becomes smaller, muscle torque would get bigger and gravity torque get bigger, muscle torque would increase accordingly. Through researching Taijiquan Needle at Sea Bottom motion process knee joint injury status, it provides better theoretical support for physiological analyzing, and make reasonable suggestions for injury prevention.

Key words: Force analysis, Lagrange's dynamical equations, exercise physiology, knee joint injury

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INTRODUCTION

Taijiquan movement is a kind of "forever young" and well received sport event. During its movement process, human skeleton takes slow and prolong movements in individual attached joints, and skeleton is changing tension and its contract angle. Sports injury is an inevitable matter in body building movement process. For traditional sport event Taijiquan, it also existing sport injury status. In order to correct and reasonable analyze sport injury causes as well as propose reasonable injury prevention measurements, taking Taijiquan Needle at Sea Bottom motion process knee joint force as research objects, so as to analyze knee joint sport injury causes through such joint force status and provide theoretical basis for knee joint injury safeguard procedures.

For Taijiquan movement Needle at Sea Bottom motion process as well as knee joint injury causes, lots of people have made efforts. Through their efforts not only propel Taijiquan widespread process, but also make reasonable suggestions for knee joint sport injury protection. Among them, Wang Xiao-Rui etc. (2012) Apply biomechanical research methods, making research on sports instituted nonphysical education major 10 female students Taijiquan trainings' right knee joint bearing huge load typical motions(Needle at Sea Bottom)possible knee joint injury mechanism, and put forward corresponding prevention measures[1]; Hao Zhi-Xiu etc.(2010) Adopt experimental method and finite element method on knee joint biomechanics researching, further deeply researching, establish effective knee joint three dimensional biomechanical model and its finite element solution that largely propel to bone and knee joint biomechanical actions research, it provides references for joint diseases prevention and cure [2];

Li Rong (2013) Apply modern science principal making technical analysis of free combat motions and diagnosis, reveal free combat motions principal, put forward reasonable training method, utilize sports biomechanics principal making analysis research on free combat motions techniques from muscle group working features and mechanics principal two aspects, with an aim to provide a certain reference for teaching and training [3-5].

This research on the basis of previous research, analyze Taijiquan Needle at Sea Bottom process knee joint force status so as to explore knee joint injury causes in such movement motion process, it provides theoretical basis and reasonable measures for knee joint sport injury protection .

TAIJIQUAN "NEEDLE AT SEA BOTTOM" MOTION DYNAMICAL ANALYSIS

Needle at Sea Bottom motion is composed of front pattern "Jade Lady Weaves Shuttles", and retreat right step, get parallel to left leg and convert into lift hand onward pattern, at this time posture is right palm turn onwards, while left palm turns downwards, it changes as Figure 1, then left palm forward intercepts and turns downwards [4, 5].

Figure 1: Taijiquan Needle at Sea Bottom motion

Needle at Sea Bottom process is as Figure 2 shows.

Figure 2: Needle at Sea Bottom motion process

Human knee force analysis

According to human construction as well as nature's kinematical features, it can regard human as 14 segments composed rigid body system model, in the system human removes right knee underneath weight calculation can be regarded as total weight minus right knee underneath two segments weights, and right knee underneath two segments weights total weight G' can be calculated with formula (1).

$$G' = mg \times (P_i + P_j) \tag{1}$$

In formula (1) m represents human total quality, g represents local gravity accelerated speed, P_i, P_j respectively represent right knee underneath two segments relative weights.

Human lower limbs each segment force analysis as Figure 3 shows.

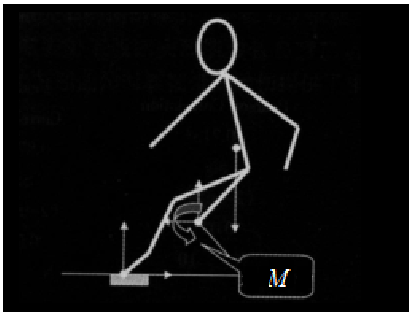

Figure 3: Needle at Sea Bottom motion human lower limb segments force analysis

In Figure 3, M represents torque direction, Taijiquan trainers' human body except for right lateral knee underneath segment system offline and right segment center's distance can be calculated through gravity center horizontal coordinate and right knee segment center horizontal coordinate; By human force analysis, image analysis, force platform data, it can get three postures human right knee joint angle, gravity torque, muscle torque, muscle torque variation, gravity torque variation as well as quadriceps femoris arm variations with second and third postures joint angles [6-9].

On the condition of human balance, it can according to mechanics conditions and force translation theorem, analyze Taijiquan Needle at Sea Bottom motion process knee force status, as formula(2)showing muscle torque M_U, friction torque M_f, support torque M_n and excluding right knee joint beneath segments gravity torque M_m relations.

$$M_U + M_f + M_n = M_m \qquad (2)$$

Dynamical principal that knee meets in "Needle at Sea Bottom" motion process

Research human knee joint in Taijiquan Needle at Sea Bottom process force status, it is hip joint, thigh and shank related to knee joint, it can simplify human lower limbs into plane two rigid bodies two freedom degree model, as Figure 4 shows.

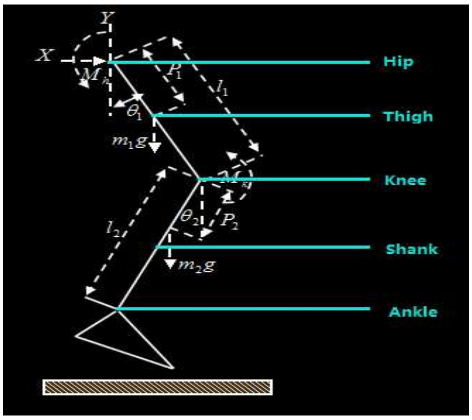

Figure 4: Human lower limb two rigid bodies two freedom degree model

In Figure 4, it involved Hip, Thigh, Knee, Shank and Ankle; apply Lagrange equations in establishing constrained particles system dynamical equations define Lagrange function L as system dynamics K and position energy P difference, as formula (3) shows.

$$L = K - P \qquad (3)$$

In formula (3), K, P can be expressed by any easy coordinate system, system dynamical equations are as formula (4) shows.

$$F_i = \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i} - \frac{\partial L}{\partial q_i}\right) \quad i = 1,2,\cdots,n \tag{4}$$

In formula (4), q_i represents dynamic energy and position energy coordinate, $\dot{q}_i$ represents its corresponding speed, F_i represents force acts on the i coordinate, thigh and shank joint variables are respectively expressed by intersection angle θ_1, θ_2 , hip joint and knee joint corresponding torque are respectively expressed by M_h, M_k , thigh and shank quality are respectively expressed by m_1, m_2, thigh and shank length are respectively expressed by l_1, l_2, thigh and shank mass center location and joint center distance are respectively expressed by p_1, p_2 , then it can know thigh mass center coordinate (X_1, Y_1) solution as formula (5), similarly shank mass center coordinate (X_2, Y_2) can also be solved by the same method [10].

$$\begin{cases} X_1 = p_1 \sin\theta_1 \quad Y_1 = p_1 \cos\theta_1 \\ X_2 = l_1 \sin\theta_1 + p_2 \sin(\theta_1 + \theta_2) \quad Y_2 = -l_1 \cos\theta_1 - p_2 \cos(\theta_1 + \theta_2) \end{cases} \tag{5}$$

System dynamic energy E_k and system potential energy E_p expressions are as formula (6) shows.

$$\begin{cases} E_k = E_{k1} + E_{k2}, E_{k1} = \frac{1}{2} m_1 p_1^2 \dot{\theta}_1^2 \\ E_{k2} = \frac{1}{2} m_2 l_1^2 \dot{\theta}_1^2 + \frac{1}{2} m_2 p_2^2 \left(\dot{\theta}_1 + \dot{\theta}_2\right)^2 + m_2 l_2 p_2 \left(\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2\right)\cos\theta_2 \\ E_p = E_{p1} + E_{p2}, E_{p1} = \frac{1}{2} m_1 g p_1 (1 - \cos\theta_1) \\ E_{p2} = m_2 g p_2 [1 - \cos(\theta_1 + \theta_2)] + m_2 g l_1 (1 - \cos\theta_1) \end{cases} \tag{6}$$

From formula (6) can get Lagrange function expressions as formula (3) shows. From formula (3) showing system dynamic equations can get hip joint and knee joint torque M_h and M_k as formula (7) shows.

$$\begin{bmatrix} M_h \\ M_k \end{bmatrix} = \begin{bmatrix} D_{11} & D_{12} \\ D_{21} & D_{22} \end{bmatrix} \begin{bmatrix} \ddot{\theta}_1 \\ \ddot{\theta}_2 \end{bmatrix} + \begin{bmatrix} D_{111} & D_{122} \\ D_{211} & D_{222} \end{bmatrix} \begin{bmatrix} \dot{\theta}_1^2 \\ \dot{\theta}_2^2 \end{bmatrix} + \begin{bmatrix} D_{112} & D_{121} \\ D_{212} & D_{221} \end{bmatrix} \begin{bmatrix} \dot{\theta}_1 \dot{\theta}_2 \\ \dot{\theta}_2 \dot{\theta}_1 \end{bmatrix} + \begin{bmatrix} D_1 \\ D_2 \end{bmatrix} \tag{7}$$

In formula (7), D_{ijk} expressions are as formula (8) shows.

$$\begin{bmatrix} D_{111} = 0 \quad D_{222} = 0 \quad D_{121} = 0 \quad D_{22} = m_2 p_2^2 \\ D_{11} = m_1 p_1^2 + m_2 p_2^2 + m_2 l_1^2 + 2 m_2 l_1 p_2 \cos\theta_2 \\ D_1 = (m_1 p_1 + m_2 l_1) g \sin\theta_1 + m_2 p_2 g \sin(\theta_1 + \theta_2) \\ D_{12} = m_2 p_2^2 + m_2 l_1 p_2 \cos\theta_2 \quad D_{21} = m_2 p_2^2 + m_1 l_1 p_2 \cos\theta_2 \\ D_{122} = -m_2 l_1 p_2 \sin\theta_2 \quad D_{211} = m_2 l_1 p_2 \sin\theta_2 \\ D_{112} = -2 m_2 l_1 p_2 \sin\theta_2 \quad D_{212} = D_{122} + D_{211} \quad D_2 = m_2 p_2 g \sin(\theta_1 + \theta_2) \end{bmatrix} \tag{8}$$

"Needle at Sea Bottom" motion caused knee joint injury correlation analysis

Through above analysis, it is clear that human habitual posture comparing with standing posture, Taijiquan trainers in Needle at Sea Bottom process, their right knee joint gravity torque and muscle torque increase by multiple times that are main causes of knee joint injury. Comparing habitual postures quadriceps femoris muscle strength to its own weight, it is significant increasing that is patellar ligament injury causes when knee joint in flexion position. Right knee minimum joint angle comparing with habitual posture, knee joint angle variance and muscle torque variables have linear relations, athletes can make sports injury prevention through changing knee joint angle.

TAIJIQUAN "NEEDLE AT SEA BOTTOM" MOTION BIOMECHANICAL PARAMETERS CORRELATION ANALYSIS

Apply SONHY T900 1210 ten thousand pixel digital camera, Kistler 9287C three dimensions force platform system、 tripod、 weighing machine and height bar in making data monitoring on Taijiquan Needle at Sea Bottom process human knee joint status, and analyze human knee joint biomechanical parameters.

Knee joint muscle torque difference analysis

As Table 1 showing human standing position and habitual posture right knee joint muscle torque data, carrying out difference analysis on data by mathematical analytic theory, get two postures muscle torques have significant differences.

Table 1: standing position and habitual two postures muscle torque values analysis

Sportsman	Standing postures muscle torque	Habitual posture muscle torque	Two postures torque ratio	Difference analysis
A	58.76	102.85	1.75	Sig.(2-tailed).000*
B	65.93	135.70	2.06	
C	54.21	98.36	1.81	
D	72.47	108.95	1.50	
E	55.94	64.97	1.16	
F	84.86	90.38	1.07	
G	47.99	77.83	1.62	
H	67.62	110.68	1.64	
I	65.00	89.53	1.38	
J	39.38	66.49	1.69	
Average value ± standard deviation	61.22 ± 12.90	94.58 ± 21.68	1.57 ± 0.30	

In Table 1, * represents correlation difference level $P < 0.05$, it is clear from data indicates that habitual position muscle torque is 1.07 to 2.06 times higher than that in standing position.

Quadriceps femoris weight bearing data analysis

In human movement process, muscle is the main body that generates strength. When in standing position posture, human knee joint surrounding muscle maintains joint stability; it can guarantee human standing posture. It is well known that every individual standing posture has a certain difference so that make every individual muscle torque has also the difference. When human in the habitual posture, its right knee joint stability mainly relies on quadriceps femoris and ligament to maintain, and while knee joint makes flexion in habitual position, it will let quadriceps femoris excessive extension that prone to be fatigued, causing patellar ligament also prone to get injured.

In order to make research on knee joint muscle tolerable loading status, it get quadriceps femoris load bearing muscle strength values and their ratios with themselves own weight in habitual position posture as Table 2 shows.

Table 2: Habitual position posture quadriceps femoris weight loading status

Sportsmen	Quadriceps femoris muscle force in habitual position posture	Sportsmen themselves weight	Weight bearing ratios
A	2093.72	558.60	3.75
B	2227.50	697.76	3.19
C	1840.92	534.10	3.14
D	2002.43	557.13	3.59
E	1521.87	453.25	3.36
F	2322.18	567.91	4.09
G	1243.78	553.21	2.25
H	2160.51	641.90	3.37
I	1552.32	509.11	3.05
J	1381.58	406.21	3.40
Average value ± standard deviation	1834.68 ± 383.76	547.21 ± 83.43	3.35 ± 0.48

From Table 2 data, it is clear that knee joint in flexion, its quadriceps femoris weight bearing ratios are in the range of [2.25, 4.09] times, arms force deceases by comparing with standing position posture, while muscle torque increasing leading quadriceps femoris muscle force increases, meanwhile muscle force increasing can cause quadriceps femoris weight bearing increases that let it prone to get tired.

Patellar ligament is the extension of quadriceps femoris tendon, quadriceps femoris extension would also accompany by patellar ligament extension, while quadriceps femoris extension will also accompany with patellar ligament extension, quadriceps muscle strength is basically also loaded by patellar ligament, so strengthen quadriceps femoris muscle force and patellar ligament attractive tension is effective way to prevent injury.

In Taijiquan movement process, steps transformation needs to be brisk, stable, clearly distinguish image and real, and knee joint always in flexion and squat status; Since femoro-tibia joint head is big and particular fosse is shallow, two particular surfaces are not adapted to each other, which causes its stability mainly relies on patella and quadriceps femoris to maintain, quadriceps femoris and patellar ligament should drive for more muscle fibers to participate energy supplying so as to maintain knee joint supporting and stability.

Knee joint force bearing and angle changes correlation analysis

In Taijiquan Needle at Sea Bottom process, habitual posture and right knee minimum joint angle postures, as Table 3 shows above two postures right knee joint angle variances and muscle torque variance as well as the two correlation analysis results.

Table 3: Knee joint force bearing and angle changes values status as well as correlation

Sportsmen	ΔM	$\Delta\alpha$	$\Delta M(g)$	ΔM - $\Delta\alpha$	ΔM - $\Delta M(g)$
A	-10.15	11.71	-2.83	Pearson Correlation -0.713* Sig.(2-tailed).021 N 10	Pearson Correlation 0.873** Sig.(2-tailed).001 N 10
B	-28.92	21.19	-37.52		
C	-3.69	16.43	-12.66		
D	-12.97	18.73	-12.94		
E	-33.48	34.16	-32.60		
F	-5.21	16.17	0.91		
G	-10.93	11.43	-6.33		
H	-9.37	10.02	-2.86		
I	-9.23	22.71	-9.67		
J	0.15	15.34	-6.45		
Average value $\pm$ Standard deviation	-12.38 $\pm$ 11	17.79 $\pm$ 7.09	-12.29 $\pm$ 13		

Note：ΔM represents muscle torque variance, $\Delta\alpha$ represents joint angle variance, $\Delta M(g)$ represents gravity torque variance, (ΔM - $\Delta\alpha$) represents muscle torque variance and joint angle variance correlation analysis, (ΔM - $\Delta M(g)$) represents muscle torque variance and gravity torque variance correlation analysis.

From Table 3 data, it is clear that two postures joint angle variance and muscle torque variance have significant correlations, the two correlation coefficient is -0.713 and turn significant negative correlations, that is to say when joint angle becomes smaller, muscle torque would become bigger.

In Taijiquan Needle at Sea Bottom process, sportsmen human body weight all falling over the right leg, meanwhile right knee joint also corresponding bear greater load, and left leg takes image step that gets relative smaller ground pressure and frictional force causing supporting torque and friction torque have smaller influence on muscle torque, therefore gravity torque is main factors that influences on muscle torque size. Human knee joint extreme minimum angle is 79.69-96.27, while to habitual posture, gravity force arm is significant increasing, therefore except for right knee beneath segment gravity would not change, gravity torque would also significant increase that causes muscle torque remarkable get increased, it shows in outside like following by joint angle deceasing, muscle torque significant increases, knee joint surrounding muscle and ligament activity get strengthen. For habitual position posture and right knee minimum joint angle posture these two postures knee joint angle variance and muscle torque variance correlation have important significances in knee joint injure prevention.

From Table 3 data, it can also concluded that two postures muscle torque variance and gravity torque variance have very significant correlations, its correlation coefficient is 0.873 that in positive correlations, that is to say when gravity torque become larger, muscle torque would increase accordingly; habitual posture and right knee minimum joint angle posture two postures muscle torque variance and gravity torque variance correlation not only are the important factors that influence on muscle torque, but also can start for gravity torque influence perspective providing reasonable opinions and measurements for knee joint injury prevention.

For gravity toque deceasing, it can be improved from reducing body weight bearing and adjusting body posture two aspects, from which body postures adjusting is most effective pathway for reducing body weight, through comparing habitual posture gravity force arm relative smaller image motion analysis, it is clear that human body slightly bend forward in completing motions, facing to right ahead and hip not so precluded all can effective reduce force arm that makes gravity ideally close to right knee joint center, can reduce muscle torque and achieve knee joint injury prevention.

CONCLUSION

Through analyzing Taijiquan Needle at Sea Bottom process human posture status, it provided space analysis image basis for Needle at Sea Bottom process knee joint force analysis. Made force analysis on Taijiquan Needle at Sea Bottom motions human knee part, it got that knee joint force bearing features as well as knee injury direct causes; For Needle at Sea Bottom motion process lower limbs features, established two rigid bodies two freedom degree dynamical model that provided theoretical basis for motion process knee joint torque analysis. To more convenient and directly research on Needle at Sea Bottom motion process knee joint injury causes and prevention measurements, it adopted image data collection and biomechanical parameters data analysis method in researching process, got that human standing position and habitual posture right knee joint muscle torques had very significant differences, while habitual position muscle torque was 1.07-2.06 higher than that in standing posture, its right knee joint stability mainly relied on quadriceps femoris and ligament to maintain, while knee joint got flexion in habitual position could let quadriceps excessive extension which easily got tired, causing patellar ligament prone to get injured; habitual posture and right knee minimum joint angle two postures, when joint angle became smaller, muscle torque would become bigger and gravity torque would become bigger, muscle torque would increase accordingly.

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