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A Human Body Model for Calculating Taiji

***Jie Gu*顾杰[1], *Huaixu Li*李怀续[1], *Jianhui Lu*卢建辉[1]**

[1]*Dept of Taiji Culture College of Handan University*

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Abstract—Handan Taiji Collage has researched the science of Taiji for many years. In the following is a review of this work. Taiji is now recognized to be a treasure of Chinese martial arts and Chinese culture, but it is important to integrate the ancient poetic descriptions of Taiji with modern science. The classic theory of Taiji is famous for giving a perfect explanation from the qualitative aspect, while leaving very large gaps in the quantitative aspects. This article uses mechanics to describe the defense-offense mechanism of Taiji and applies a scoring-criteria to Taiji for martial arts application. A human body-based math model is established to simulate the defense-offense moves, and dynamic and static formulas for releasing force are derived. To aid these calculations, which can be quite complex, we developed a software program with VBA (Excel visual basic for application), which can be used to calculate the defense and offense capabilities of Taiji and other martial arts.

Introduction

A force in Taiji has the same definition as a force in physics. That is, force is the interaction between objects, where Newton's second law gives a quantitative relationship between force, mass, and acceleration, with the well-known equation force = mass acceleration.

However, at this moment, the concept of "strength" is not well defined in the martial arts world, and various authors have used the word, strength, in different ways. Strength is often used in reference to internal aspects. In other words, the quality or state of being strong in body, or in muscular power and vigor[1]. In contrast, Jie Gu[1] chose to employ a mechanical definition for strength: where strength is related to momentum. Linear momentum in mechanics is the product of mass and velocity, and angular momentum is the product of rotational inertia and angular velocity. With these strict definitions of strength and force, it is then possible for a practitioner's Taiji's defense-offense ability to be adequately quantified. Jie Gu, et. al.[2] also discussed the mechanical mechanism of "explosive" and "sequential" strength, where explosive strength was defined as a relative momentum (in other words, the release strength, by the relative motion among the body parts) and sequential strength as supporting momentum, which can be described as the gradual release of energy, which stems from the supporting area of the body through the body part delivering the energy and its delivery to the opponent.

In this way, internal force and internal strength are the internal quantities of the human body, but they fully conform to previous accepted definitions of mechanics.

External force thus refers to the exertion of external forces on the human body, such as gravity, friction, and normal, perpendicular forces on the soles of the feet (such as those exerted on and from the ground). External momentum are those that collide with the human body.

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In terms of strength, the opponent's strength may also act on us the defender's balance and influence the defender's mobility. It should be noted in this model the internal force/strength and the external force/strength have exactly the same mechanical definition. The difference is only that the former acts on the inside of the human body, and the latter is the external exertion on the human body.

Jie Gu et. al.[3,4] then introduced, for the first time, the human body plane rigid body model to the study of Taiji. This model includes several parameters that relate to the human frame, mass, speed, horizontal attack force, gravity, ground reaction force, friction force and several other secondary factors.

Applying this model to the mechanical analysis of Taiji under the action of horizontal force, five important conclusions could be drawn: the center of gravity of the human body must be within what was termed the *Support Surface*, which is usually the ground, in order to maintain balance; foot slip and root loss (root loss being when the normal force equals zero, which means the foot is in the air, without contact force to the floor) are considered to be critical conditions for maintaining balance: the human body is balanced within critical conditions, exceeding any critical condition will cause the human body to lose balance, and put the practitioner at a major disadvantage; the horizontal attack force depends on the friction force of the soles of the feet, the overall momentum of the human body and the momentum of the relative movement of the limbs; internal force creates momentum and transmission force.

In prior studies, the mechanical principles of technical skills such as the moves known as "throw like an arrow", "introduce to empty", and "four ounce deflect thousand strength" were also demonstrated, with numerical examples, and these were then developed and modeled. The analysis showed that with a lower bow stance, it was possible to generate a greater horizontal delivered pushing force; and a lower sitting stance permitted the practitioner to generate a greater horizontal pulling force, which means, the lower the stance, the greater the delivered force, but this is only achieved with a reduction in flexibility and mobility.

The higher the stance, the lower the delivered force, but the higher the flexibility. Thus, a middle stance takes into account the advantages and disadvantage of various aspects.

In further studies by Jie Gu[5] it was demonstrated that a middle stance of Yang Taiji is optimal for both self-cultivation and martial arts practice, through quantitative analysis of knee bending and internal force. This differs from prior studies, which were unable to define the advantages quantitatively.

Since these studies various incremental improvements have consistently been made to the model[6-8]. In the prior studies, the force in martial arts comes from three *sources*: a transmission force, the overall impact force and the relative impact force. Also studied were the influence of the "three sources of force" (Supporting frame force, overall body momentum force, and a force linked to the relative momentum between body parts) used in the Yang Chengfu Taiji's bow stance on a pushing force.The conclusion is that the bow stance is suitable for delivering a net pushing force, and the "three sources of power" all increase the ability of the bow stance to generate a pushing force.

The literature analyzed the influence of the "three sources of force" on the pulling force in the Yang Chengfu Taiji's sit stance. The conclusion is that a sit stance is suitable for delivering pulling force, and the "three sources of power" all increase the ability of the sit stance to generate pulling force.

Finally, study[9] extended the horizontal force model that was introduced in Jie Gu[3] to a three-dimensional force model. In this, the mechanical principle of the human body model under the action of horizontal, vertical and lateral forces was demonstrated. The quantitative analysis formulas of stability, lost root and slipping critical conditions were also deduced, which brought the model closer to reality and created better universal significance.

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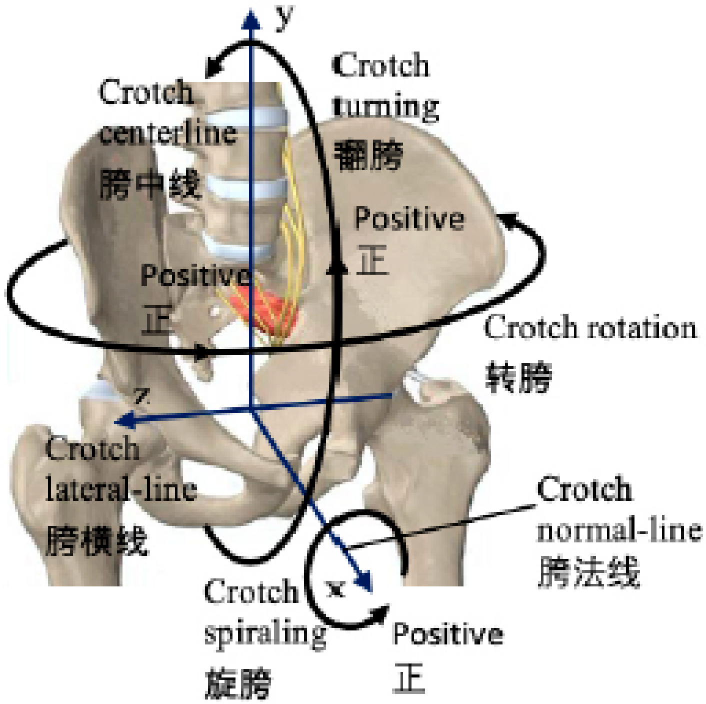

Fig. 1. Image showing spiraling, rotating and turning motions around the crotch.

This was further improved in a study that established a 3D rigid body model of the human body, and introduced the dimension of the depth direction, and added a moment vector to the external force[10].

It is sometimes said that Taiji is a martial art that involves both "moving with every body part and stillness with every body part"[11]. To match the "stillness" component, the human body is considered to be a rigid body with a defined mass and six degrees of freedom, and the connecting hand is a rigid body, with its own mass and six degrees of freedom.

In this model, a generalized force that is composed of three directional forces (in the x y and z directions) and three moments (where the moments describe spiraling or wrapping actions) is developed that permits the model to include all the possible forces in any direction. These forces act together on the human body.

The generalized force can be used to simulate the directional defense and offensive ability of Taiji and the generated model includes the spiral effect of thread drawing and thread wrapping (by taking into account the orientation, motion and the corresponding moments).

The advantage is the developed 3D model concisely includes the frame of the human body, the overall mass, the connecting hand mass, the overall moment of inertia, the connecting hand moment of inertia, the overall motion, the connecting hand motion, the overall rotation, the connecting hand rotation, the attack force and moment, the gravity, the ground reaction force, the friction force and many other factors.

The 3D model is also able to analyze the mechanical principles of complex movements such as turning waist, rotating crotch, and spiraling connecting hand; it analyzes the difference between along and opposite stances; it analyzes the influence of width of the stance; and thus it provides a very detailed scientific method and a solid theoretical basis for the practice and study of Taiji.

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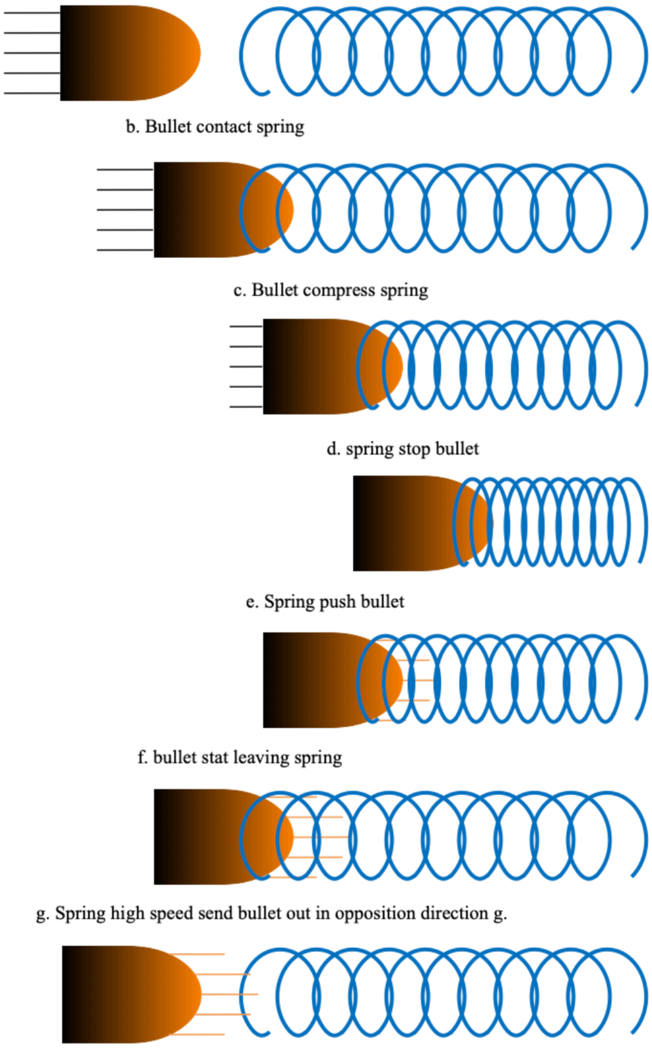

Fig. 2. Interactions between a "bullet" and a spring

The combat functionality of Taiji is most often reflected in various postures. Because internal force often arises from the actions of different body parts, which are synchronized, and combined to create an attack, Jie Gu et al.[12] then proposed an external multi-force system in the 3D model for Taiji and compiled a software program to calculate three connecting hand forces (the various force vectors).

This model expands upon the prior single force theories and concisely includes the frame of the human body and the connecting hand, translation and rotation motions, external force and several other factors. The software is used to quantitatively analyze the dynamic and static effects of Taiji postures.

The next study[13] outlined the mechanics of Taiji. It put forward the concept that Taiji is the spring (which means to deform like an elastic cushion and to recover). This is shown schematically in Fig. 2.

To operate at the highest level, the martial art practitioner must know oneself and one's enemy. In Taiji, the eight methods (bouncing, diverting, squeezing, pressing, grabbing, lateraling, elbowing, and banging) are the tactical principles of Taiji; the five steps

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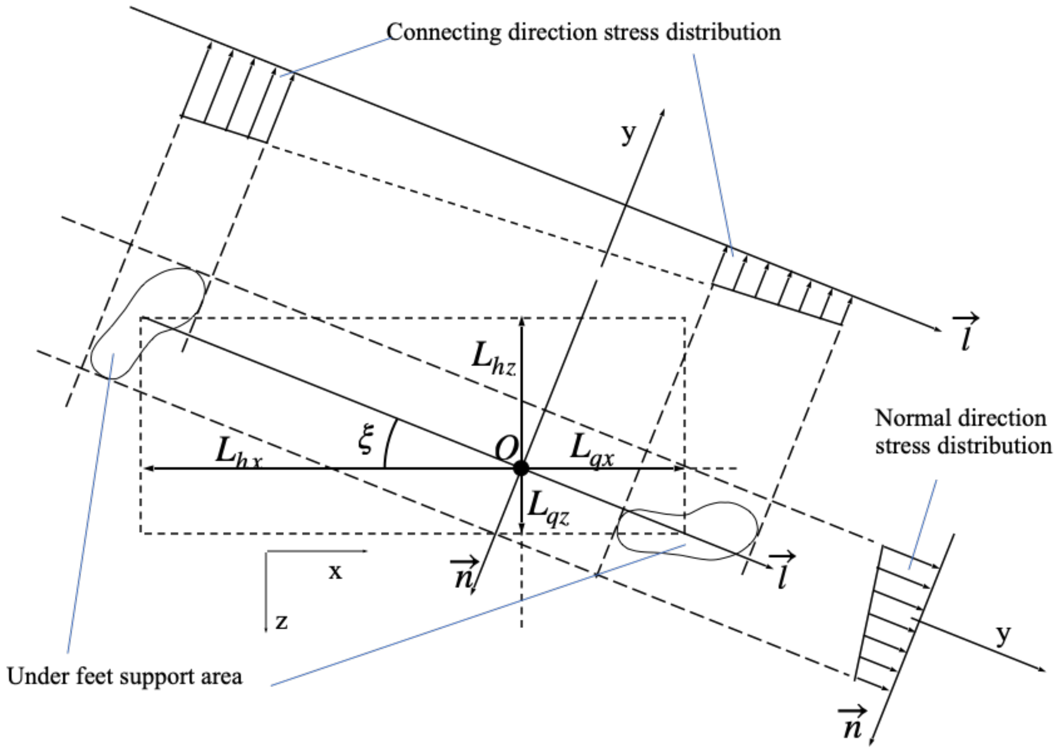

Fig. 3. View from above of the bilinear elastic stress distribution.

(forward, backward, leftward, rightward, and centering) are the balance principles; and connecting, linking, sticking and following are the strategic principles of Taiji.

Within reference 14, the authors then used the 3D model that they had developed to calculate all thirty-seven non-repetitive postures of Yang large frame Taiji.

The basic forms of Taiji are routines, weapons, push hands, and free fight; and the basic content and connotation of Taiji is postures.

In essence, Taiji postures are “extracts” of actual combat, and the sense of defense-offense is a blend in the movements of “running water and floating cloud”.

In total thirty-seven postures are compiled into the "Primary Yang's 37" routine. Through the analysis and calculation of these Primary 37 postures, it was proven that the ancient art of Taiji can be analyzed in a more scientific, standardized, and modernized manner.

In reference 15, the authors next introduced the concept of the influence of a stress distribution on the sole of the foot into the mechanical model of Taiji.

Using standard theories found in material mechanics, the mechanical stresses on the soles of the feet are assumed to be a linear elastic distribution. These stresses are distributed in a trapezoidal shape, at the practitioner’s feet (Fig. 3.).

Within this model, the stress is considered to be zero *between* the two feet, and the trapezoids at both ends are connected in a straight line, and the stress at any place *on the sole of the foot* cannot be negative. This is important, because, in this way, for the first time, a stress between the person’s feet and the floor was introduced into the field of elastic mechanics.

Calculations show that linear elasticity theory increases the model’s accuracy, when compared with the point contact theory, which the authors had proposed earlier[3]. Overall, the accuracy of the point contact

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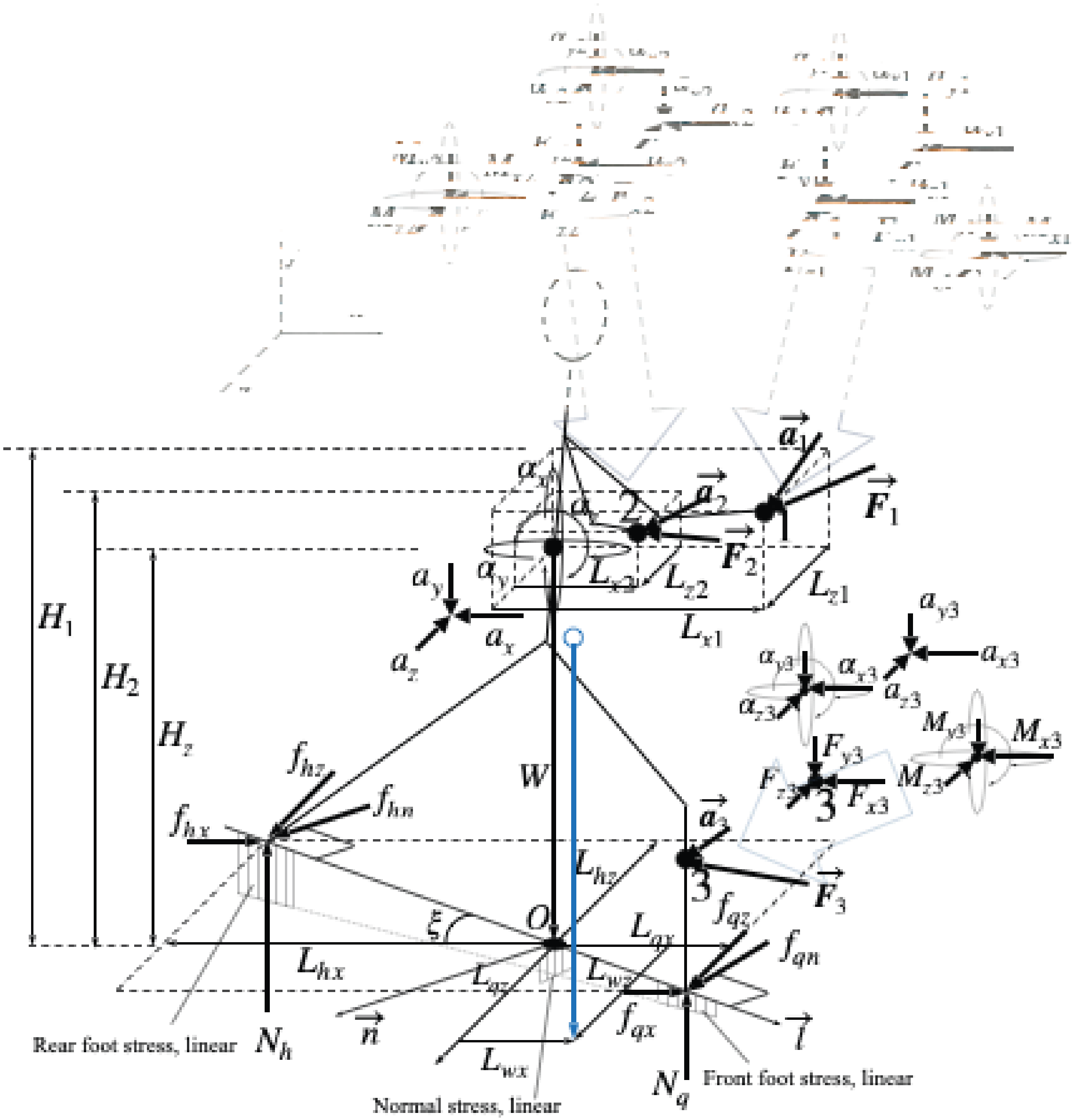

Fig. 4. Bi-elastic multiple force 3D model.

theory is considered to be very good when the distance between the feet is large, but it was still observed that the error increases when the distance between the two feet becomes closer.

The foot-ground contact surface, described in reference 15, employed two naturally separated areas: the front foot and the rear foot. However, it was noted that the problem with this approach is sometimes a practitioner may stand on only one foot, which means, in this case, there is only one grounded area.

In order to address the issue of single foot stances, the study in reference 16 discussed the influence of the continuous area of sole stress on the mechanical model of Taiji, and it divides the continuous surface into two parts based on push or pull, and the critical condition of a single foot stance was then calculated.

Reference 17 then proposed a longitudinal point and normal elastic model. In the connecting direction of the two feet, a point contact theory was used because the accuracy of the point contact theory is good

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$$F_x'' - f_{qx} - f_{hx} = 0 \quad F_x'' = \sum F'_{xi} - ma_x \quad F'_{xi} = F_{xi} - m_i a_{xi}$$

$$F_y'' - N_q - N_h = 0 \quad F_y'' = W + \sum F'_{yi} - ma_y \quad F'_{yi} = F_{yi} - m_i a_{yi}$$

$$F_z'' - f_{qz} - f_{hz} = 0 \quad F_z'' = \sum F'_{zi} - ma_z \quad F'_{zi} = F_{zi} - m_i a_{zi}$$

$$\sigma = \sigma_0 + \delta(l - l_0) \geq 0 \ everywhere$$

$$J_0 = \int_q n_A dl + \int_h n_A dl \quad J_1 = \int_q l n_A dl + \int_h l n_A dl \quad J_2 = \int_q l^2 n_A dl + \int_h l^2 n_A dl$$

$$\sigma_0 J_0 + \delta(J_1 - l_0 J_0) = F_y'' \quad l_0 = J_1 / J_0$$

$$\begin{cases} \int_q \sigma l n_A dl + \int_h \sigma l n_A dl = M_n \\ M_n = (M_z'' - \sum F'_{xi} H_i) L_{qx}/L_q + \sum F'_{yi} L_{si} + (mg - ma_y) L_w - (M_x'' + \sum F'_{zi} H_i) L_{qz}/L_q \\ M_x'' = \sum M_{xi} - ma_z H_z - I_x \alpha_x - \sum I_{xi} \alpha_{jx} \quad M_z'' = \sum M_{zi} + ma_x H_z - I_z \alpha_z - \sum I_{zi} \alpha_{zi} \\ M_{n0} = -[(\sum M_{zi} - \sum F'_{xi} H_i) L_{qx}/L_q + \sum F'_{yi} L_{si} \\ +(mg - ma_y) L_w - (\sum M_{xi} + \sum F'_{zi} H_i) L_{qz}/L_q] \\ L_q = \sqrt{L_{qx}^2 + L_{qz}^2} \quad L_h = \sqrt{L_{hx}^2 + L_{hz}^2} \quad L_{si} = \frac{L_{xi} L_{qx} + L_{zi} L_{qz}}{L_q} \quad L_w = \frac{L_{wx} L_{qx} + L_{wz} L_{qz}}{L_q} \end{cases}$$

$$\sigma_0 = F_y'' / J_0 \quad \delta = (F_y'' J_1 - M_n J_0)/(J_1^2 - J_0 J_2)$$

$$M_{n0} > 0 \quad \begin{cases} front\ input\ \sigma_{q\_toe} = F_y'' J_0 + (F_y'' J_1 - M_n J_0)(L_q + l_{qq} - \frac{J_1}{J_0})/(J_1^2 - J_0 J_2) \geq 0 \\ front\ critical\ \sigma_{q\_heel} = F_y'' J_0 + (F_y'' J_1 - M_n J_0)(L_q - l_{qh} - \frac{J_1}{J_0})/(J_1^2 - J_0 J_2) \geq 0 \end{cases}$$

$$M_{n0} < 0 \quad \begin{cases} rear\ input\ \sigma_{h\_heel} = F_y'' J_0 + (F_y'' J_1 - M_n J_0)(-L_h - l_{hh} - \frac{J_1}{J_0})/(J_1^2 - J_0 J_2) \geq 0 \\ frear\ critical\ \sigma_{h\_toe} = F_y'' J_0 + (F_y'' J_1 - M_n J_0)(-L_h + l_{hq} - \frac{J_1}{J_0})/(J_1^2 - J_0 J_2) \geq 0 \end{cases}$$

$$N_q = \sigma_0 \int_q n_A dl + \delta \int_q (l - J_1/J_0) n_A dl \geq 0 \quad N_h = \sigma_0 \int_h n_A dl + \delta \int_h (l - J_1/J_0) n_A dl \geq 0$$

$$\begin{cases} \tan\phi_{xz} = \sqrt{F_x''^2 + F_z''^2} / F_y'' \leq \mu \\ if \ |F_x''| + |F_z''| \neq 0 \quad \tan\psi = F_x''/F_z'' \\ else \ |F_x''| + |F_z''| = 0 \quad \tan\psi = \psi = 0 \end{cases} \quad \begin{cases} f_q = N_q \tan\phi_{xz} \\ f_{qx} = f_q \sin\psi \\ f_{qz} = f_q \cos\psi \end{cases} \quad \begin{cases} f_h = N_h \tan\phi_{xz} \\ f_{hx} = f_h \sin\psi \\ f_{hz} = f_h \cos\psi \end{cases}$$

$$\left\{ \begin{matrix} M_q = \sigma_0 \int_q l n_A dl + \delta \int_q l(l - J_1/J_0) n_A dl \\ L_{ql} = M_q / N_q \end{matrix} \right. \quad \left\{ \begin{matrix} M_h = \sigma_0 \int_h l n_A dl + \delta \int_h l(l - J_1/J_0) n_A dl \\ L_{hl} = M_h / N_h \end{matrix} \right.$$

$$\begin{cases} -M_y'' + M_{yy} - f_{qn} L_{qw} + f_{hn} L_{hw} + M_{fy} = 0 \\ M_y'' = \sum (M_{yi} - \alpha_{yi} I_{yi}) - \alpha_y I_y \quad M_{yy} = -\sum F'_{xi}(L_{zi} - L_{wz}) + \sum F'_{zi}(L_{xi} - L_{wx}) \\ M_{fy} = f_{qx}(L_{ql} \sin\xi - L_{wz}) - f_{qz}(L_{ql} \cos\xi - L_{wx}) \\ -f_{hx}(-L_{hl} \sin\xi + L_{wz}) + f_{hz}(-L_{hl} \cos\xi + L_{wx}) \\ L_{qw} = \sqrt{(L_{ql} \cos\xi - L_{wx})^2 + (L_{ql} \sin\xi - L_{wz})^2} \\ L_{hw} = \sqrt{(-L_{hl} \cos\xi + L_{wx})^2 + (-L_{hl} \sin\xi + L_{wz})^2} \end{cases}$$

$$\tan\xi = L_{qz}/L_{qx} \quad f_{qn} + f_{hn} = 0$$

$$\begin{cases} f_{qn} = \frac{-M_y'' + M_{yy} + M_{fy}}{L_{qw} + L_{hw}} \quad f_{hn} = -\frac{-M_y'' + M_{yy} + M_{fy}}{L_{qw} + L_{hw}} \\ \tan\phi_{qn} = f_{qn}/N_q \leq \pm\mu \quad \tan\phi_{hn} = f_{hn}/N_h \leq \pm\mu \end{cases}$$

$$f_q^{\square} = (f_{qx} - f_{qn} \sin\xi) i^{\square} + (f_{qz} + f_{qn} \cos\xi) k^{\square} \quad f_h^{\square} = (f_{hx} - f_{hn} \sin\xi) i^{\square} + (f_{hz} + f_{hn} \cos\xi) k^{\square}$$

$$\begin{cases} \tan\phi_q = \sqrt{(f_{qx} - f_{qn} \sin\xi)^2 + (f_{qz} + f_{qn} \cos\xi)^2} / N_q \leq \mu \\ \tan\phi_h = \sqrt{(f_{hx} - f_{hn} \sin\xi)^2 + (f_{hz} + f_{hn} \cos\xi)^2} / N_h \leq \mu \end{cases}$$

$$M_{ceLim} > \begin{cases} M_{ce} = -\sum M'_{xi} \cos\xi - \sum M'_{zi} \sin\xi + \sum F'_{xi} H_i \sin\xi - \sum F'_{zi} H_i \cos\xi \\ +\sum F'_{yi}(L_{zi} \cos\xi - L_{xi} \sin\xi) + (mg - ma_y)(L_{wz} \cos\xi - L_{wx} \sin\xi) \\ -(ma_x \sin\xi - ma_z \cos\xi) H_z + I_x \alpha_x \cos\xi + I_z \alpha_z \sin\xi \\ M'_{xi} = M_{xi} - I_{xi} \alpha_{xi} \quad M'_{zi} = M_{zi} - I_{zi} \alpha_{zi} \end{cases}$$

Fig. 5. Computational code and an example of the Application of the Taiji Model to Various Taiji Stances

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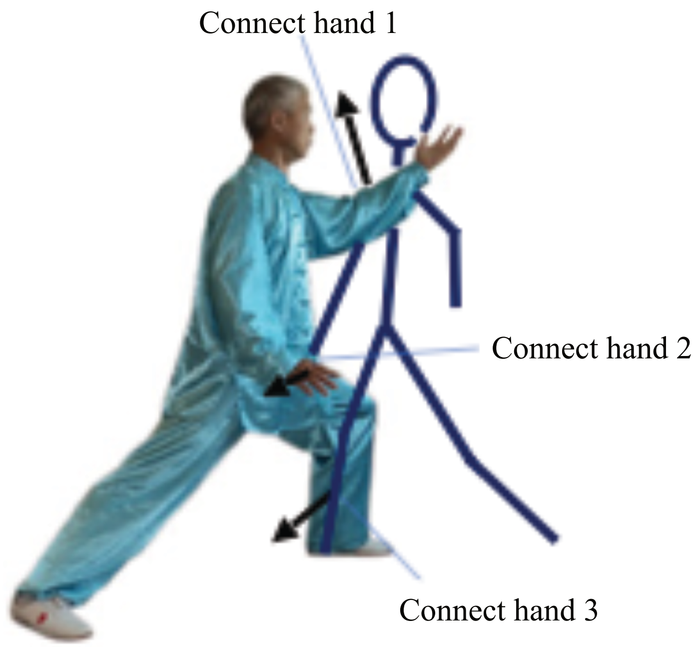

Fig. 6. Left horse part mane. Due to the initial structure used in the computer program both feet and hands and even elbows and knees were referred to as "connected hands." This will be changed in later iterations of the program.

stance classification	1st connecting hand horizontal distance	1st connecting hand lateral distance	1st horizontal force ratio	1st vertical force ratio	1st lateral force ratio	1st horizontal force	1st vertical force	1st lateral force	Initial force/moment	Normal Stability moment
	L_{x1}	L_{z1}	$\varepsilon_{Fhf}(1)$	$\varepsilon_{Fhf}(2)$	$\varepsilon_{Fhf}(3)$	F_{x1}	F_{y1}	F_{z1}		
	m	m	no	no	no	N	N	N		
left horse part mane left hand	0.4	-0.2	1	0.30	-1.5	68.3	20.5	-102.4	51.2	67.2
left horse part mane left hand and right hand	0.4	-0.2	1	0.30	-1.5	193.4	58.0	-290.1	145.0	67.2
left horse part mane left hand, right hand and left foot	0.4	-0.2	1	0.30	-1.5	252.4	75.7	-378.6	189.3	67.2

stance classification	Critical condition	front foot normal force	rear foot normal force	front foot force tangent	rear foot force tangent	moment in normal direction	2nd connecting hand height	2nd connecting hand horizontal distance	2nd connecting hand lateral distance	2nd horizontal force ratio	2nd vertical force ratio	2nd lateral force ratio
		N_q	N_h	$\tan\varphi_q$	$\tan\varphi_h$		H_2	L_{x2}	L_{z2}	$\varepsilon_{Fhf}(7)$	$\varepsilon_{Fhf}(8)$	$\varepsilon_{Fhf}(9)$
		N	N	no	no		m	m	m	no	no	no
left horse part mane left hand	1N los	304.7	303.8	0.30	0.18	67.2						
left horse part mane left hand and right hand	1F sli	195.0	393.0	0.50	0.31	61.0	0.8	0.05	0.2	-0.3	-0.3	1
left horse part mane left hand, right hand and left foot	1F sli	224.8	-413.7	0.50	0.21	15.2	0.8	0.05	0.2	-0.3	-0.3	1

Table 1. Three examples of force delivery within horse part mane.

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when the feet are a distance apart. In the direction normal (perpendicular) to the two feet, the contact surface (this being the ground) is considered to be continuous and it cannot be divided into two distant points. This means the normal direction must be evaluated by linear elastic theory, using the normal stabilizing moment provided in reference 16.

The model that was formed is a 3D rigid body with mass and moment of inertia. There are also the critical conditions of front and rear foot loss and slippage, plus normal instability.

This permitted the common push hand moves of the traditional Yang style to be compiled into a pairing routine. The stability and delivering force in the confrontation process were also calculated for all push hand moves by using the longitudinal point and normal elastic model.

These confrontation moves include the commence, opposite four frontals, horizontal circle single hand push, vertical circle single hand push, flip-flop single hand push, opposite double hand push, follow four frontals, live step opposite four frontals, serial step follow four frontals, large divert, closing form. A quantitative analysis of martial arts confrontation was subsequently performed, for the first time.

With the model now reasonably developed, reference 18 then applied linear elasticity theory to the connecting direction of the two feet on the basis of reference 17, see figure 5.

This revised code has now become part of a computer program to help determine the forces exerted by a practitioner during specific Taiji moves. In the following an example is given to help illustrate the calculation process.

Within reference 18, the authors applied linear elasticity theory to the connecting direction of the two feet that was previously described in reference 16. In this way, a bi-elastic linear, multi-force, 3D model was established, see Fig 5b, form which various mathematical Formulas were derived.

Specifically, Fig. 5b represents the movement left horse part mane for defense-offense. In this movement the opponent sets out his right foot and attacks with his right palm, and the defender steps out with the left foot and blocks the opponent's right foot, the defender's right hand grabs the opponent's right hand, and the left arm comes under the opponent's right arm and up towards the opponent's chest and between the armpits. Table 1 analyzes the three types of forces delivered and their combinations.

In the first movement (see row 1 in table 1), only "connected hand 1" delivers a force, that is, only the defender's left arm strikes forward, upward, and leftwards, and the ratio of the force direction vectors are F_{x1}:F_{y1}:F_{z1}=1:0.3:-1.5, where the subtitles x1, y1, and z1 represent the left hand, and x2,y2 and z2 the right hand. The calculated critical force, shown here in green, is F_{x1}:F_{y1}:F_{z1}=68.3:20.5:-102.4.

In this study, F_{z1} is the force that moves directly to the left, which acts at a height of 1.1 meters and it generates a moment of 102.4x1.1=112.6(Nm). This moment is much larger than the opponent's normal stabilizing moment of 67 Nm.

There is an assumption here, which is the opponent's right foot is locked by the friction force, and the defender's force and the friction force of the sole of the opponent's foot form a moment, to knock down the opponent. If the opponent responds in time and moves his right foot in the air, the attack will not achieve the expected effect.

In the second case (row 2 in the table), hands 1 and 2 deliver force together, that is, the additional right hand delivers grabbing force, and the ratio of the grabbing force direction is F_{x2}:F_{y2}:F_{z2}=-0.3:-0.3:1. In this case, the critical force at "connect hand 1" is calculated as F_{x1}:F_{y1}:F_{z1}=193.4:58.0:-290.1.

In this movement Force F_{z1} has more than doubled. In addition, the grabbing force that the right hand (connect hand 2) can deliver in this case is F_{x2}:F_{y2}:F_{z2}=-58.0:58.0:193.4. The lateral force F_{z2} and the lateral force F_{z1} form a lateral moment of 193.4 x 0.3 = 58.0 Nm.

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stance classification	2nd horizontal force	2nd vertical force	2nd lateral force	3rd connecting hand height	3rd connecting hand horizontal distance	3rd connecting hand lateral distance	3rd horizontal force ratio	3rd vertical force ratio	3rd lateral force ratio	3rd horizontal force	3rd vertical force	3rd lateral force
	F_{x2}	F_{y2}	F_{z2}	H_3	L_{x3}	L_{z3}	$\varepsilon_{cu}(13)$	$\varepsilon_{cu}(14)$	$\varepsilon_{cu}(15)$	F_{x3}	F_{y3}	F_{z3}
	N	N	N	m	m	m	no	no	no	N	N	N
left horse part mane left hand	0.0	0.0	0.0							0.0	0.0	0.0
left horse part mane left hand and right hand	-58.0	-58.0	193.4							0.0	0.0	0.0
left horse part mane left hand, right hand and left foot	-75.7	-75.7	252.4	0.3	0.24	-0.12	-0.1	0.2	1	-25.2	50.5	252.4

Table 1. Continued: Three examples of force delivery within horse part mane.

Overall this moment can be considered very effective. The reason is when we grab, we can intentionally add spiral wrapping, in order to turn the opponent's arm into what is termed an "anti-joint state" and the two movements, at the same time, will then have a multiplier effect.

In more detail, the defender's right hand is internally rotated, causing the opponent's right hand to be externally rotated, which will usually cause the opponent to make the decision to fall over, in order to prevent joint injury.

In addition, this anti-joint movement will help lock the opponent's right foot. The doubled lateral force of the defender's "connect hand 1" and the friction force of the opponent's sole of the foot thus forms produces a lateral moment of 290.1 x 1.1 = 319.1 Nm. The sum of the two moments is then 58.0 + 319.1 Nm. This magnitude is 5 times the opponent's normal stabilizing moment, which means the probability of the opponent falling to the ground is substantial. Of course, if the opponent is fast, and the anti-joint movement is resolved in time and the right foot is withdrawn in time, there is still the possibility of escape.

In the third case (row 3 in table1), connect hand 1 and 2 and 3 all act to together to deliver a combined force. That is, the additional left foot delivers a blocking force, where the ratio of the blocking force vectors are measured to be F_{x3}:F_{y3}:F_{z3}=-0.1:0.2:1.

In this case, with the addition of the x3,y3, and z3 components, the calculated critical force at connect hand 1, along the three now rises to F_{x1}:F_{y1}:F_{z1}=252.4:75.7:-378.6.

As can be seen, force along the F_{z1} direction has increased by a substantial amount. The calculated critical force at connect hand 2 is F_{x2}:F_{y2}:F_{z2}=-75.7:-75.7:252.4; and the lateral grabbing force F_{z2} has also increased.

In addition, the blocking force that the left foot (which the preliminary computer program calls "Connect Hand 3") is able to deliver is F_{x3}:F_{y3}:F_{z3}=-25.2:50.5:252.4.

Though it is possible to describe here the various forces generated in more detail, this has been done in prior publications, and the important point is this data produces a mathematical description, which confirms that because the total deliverable moment at 492.2 Nm is 7 times greater than the opponent's normal stabilizing moment, this move creates a grabbing, anti-joint function that also intercepts the possibility of the opponent making an escape. In this three-way, simultaneous attack, the opponent will fall. This use of a mathematical approach can thus assist practitioners in determine the optimal approach to use, and it is possible that it may aid in the development of new more efficient moves.

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