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The regression analysis on fast strength and punch speed of the left foot and right foot in Sanda hook based on kinematic mechanics

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ABSTRACT

In order to make the level of Chinese Sanda athletes can improve rapidly, this paper firstly conducts the mechanical analysis and dynamic analysis on the upper body and left and right arms of Sanda athletes when do flat hooks, obtains the potential energy produced by the various parts of the body when Sanda athletes do flat hooks. Then it analyzes that when the athletes do flat hooks, the correlation between the strength parameters and the punch speed of the left foot and right foot is more significant; the ratio of the strength of the left foot and right foot and the athlete's body weight, and the time for the left foot and right foot to reach the maximum strength has quadratic function relationships with the punch speed, the extreme value of the right foot is $x = 0.204, y = 5.643$, and the extreme value of the left foot is $x = 0.189, y = 5.587$. And as can be seen from the results, athletes' enhancing the strength and force speed when pedaling the ground in training, and shortening the force time are in favor of the punch speed of hooks.

KEYWORDS

Mechanical analysis;
Moment of inertia;
T test;
Sanda uppercut;
Regression analysis.

INTRODUCTION

Sanda comes from the earliest ancient China, also known as Sanshou, is evolved unarmed self-defense method to resist the invasion of the beast, hunt for food, as well as confront to survive against a variety of fights when the ancient ancestors are in the absence of consciousness by using weapons, and it is the essence of Wushu gestated by 5,000 years of Chinese history. With the continuous development of human society Sanda's technology is constantly absorb the essence of a variety of traditional martial skills with the changing of the time, and forms into modern Wushu Sanda through the long-term formation and the adjustment. Chinese Sanda began to sprout from the 1970s to the eighties, from the beginning of learning to the later trial training, in 1982, Chinese Sanshou competition rules were developed, and the National Wushu confrontational project exhibition will be held annually with the spirit of "positive and safe". In 2012 China established a national team in the field of martial arts for the first time; in the meantime, Chinese Sanda has rapidly grown up in the constant learning.

Modern Chinese Sanda competition is in the form of traditional Da Lei, which takes one falling out of the ring first lose as the rules and determines winning and losing in three games. It is very different from the simple and quick taekwondo and Western boxing, and is more different from the mix, capture and swap-based judo, but also is different from the elbow, knee and other ferocious attack-based Muay Thai. During the Sanda competition athletes are prohibited to use the elbow, knee and anti-joint martial skills, but also do not allow attacks the opponent's neck, crotch and brain. The skills of Sanda have straight and curved forms two main kinds. Sanda pays attention to fist and foot use simultaneously, and the fist technique takes the whipping, punching, slashing and lifting as the principal thing, and the leg technique takes the kicking, pedaling, sweeping, whipping, swinging and hooking as the principle thing. When close to each other, mostly attack on each other in the form of the rapid fall, the main focus of the theory is to destruct the gravity center and the waving circle, and then play the clip play fall and react fall. Defense takes the contactless defense and contact defense as the principal thing, and in the defense of players good use of hooks will play a good role, the paper will analyze and study it.

THE MODEL BUILDING AND SOLVING

The basic steps of uppercut

Hooks is an arc-type close combat boxing, and it is more for their own defense in the competition. It can be divided into four kinds according to technology, upper hooks, oblique hooks, flat hooks and side hooks; but the basic position of the four hooks is basically the same, just the hit sites and directions are different; the following studies the produced moment of inertia by the athletes' body when do hooks taking the flat hook for example. When Sanda athletes do flat hooks action, first he must show the basic combat posture, then the upper body drive the waist rotate to the right, and right foot pedal to rotate the hip joint while pulling the right shoulder to right, rotate the body to the left and make the right fist hook out laterally, left fist protect the jaw, after completing the action then rotate the body to the right and make the left fist hook out laterally. In this process, the forearm and the upper arm should maintain the $90°$ angle. Figure 1 and Figure 2 are the positive and side schematics of athletes when do hooks.

Kinetic analysis of athletes' flat hook

When Sanda athletes do flat hooks, first rotate the upper body drive the waist rotate to the right, and right foot pedal to rotate the hip joint while pulling the right shoulder to right, rotate the body to the left and make the right fist hook out laterally, left fist protect the jaw, after completing the action then rotate the body to the right and make the left fist hook out laterally, so this process can be seen as athletes do fixed-axis rotation around the body axis. Figure 3 is a schematic diagram of the athletes' fixed-axis rotation.

Figure 1 : The front schematic of athletes' hook

Figure 2 : The side schematic of athletes' hook

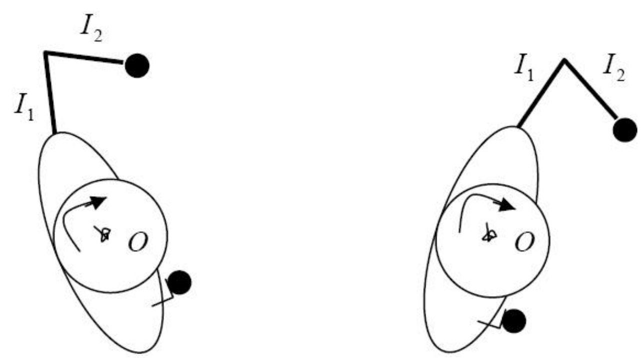

Figure 3 : The overlooking schematic of athletes' fixed-axis rotation

Inertia means the measurement of the generated inertia by the rigid body rotates around a fixed axis, it is only related to the rigid body's shape, quality and location of the axis, and is independent of the angular velocity and other parameters. Players' body will be treated as rigid body, and then the moment of inertia generated by the athletes is:

$I = \Sigma m_i r_i^2$

The athlete's body parts are seen as a rigid body with continuous mass distribution, therefore:

$I = \iiint_v r^2 dm = \iiint_v r^2 \rho dV$

In the above formula m_i is the quality of each mass unit, r is the vertical distance of each mass unit to the axis, and ρ is the density of mass unit. The following seeks the inertia of each point on athletes that is the inertia tensor. The rotation tensor $\overset{\leftrightarrow}{J}_c$ of players' rotation around the center of mass O is:

$$\overset{\leftrightarrow}{J}_c = \iiint_v \rho(r^2 \overset{\leftrightarrow}{1} - \vec{r}\vec{r})dV$$

In the Formula $\vec{r} = r_1 \vec{e}_1 + r_2 \vec{e}_2 + r_3 \vec{e}_3$ means the radius vector of any point o on the athletes' body; $\vec{r}\vec{r}$ is the product of two vectors; while:

$$\overset{\leftrightarrow}{1} = \begin{bmatrix} 1 & & \\ & 1 & \\ & & 1 \end{bmatrix}$$

is the unit tensor of the athletes' body. Athletes' unit orthogonal curvilinear frame is $(C; \vec{e}_1, \vec{e}_2, \vec{e}_3)$.

The moment equations of athletes' rotation tensor $\Sigma \vec{M}_c$ means the resultant moment vector for athletes' rotation around point O, $\vec{\omega}$ means the angular velocity vector of athletes in the inertial system, $\vec{\alpha}$ is the vector for the angular acceleration, the athletes' rotation tensor is $\overset{\leftrightarrow}{J}_c$, therefore, the torque equation of athletes' rotation tensor is:

$$\Sigma \vec{M}_c = \overset{\leftrightarrow}{J}_c \bullet \vec{\alpha} + \vec{\omega} \times \overset{\leftrightarrow}{J}_c \bullet \vec{\omega}$$

Project the torque equation to the axis x, y, z in the three-axis coordinate system, the torque equation on direction of each coordinate axis can be obtained.

The moment of Inertia of athletes' elbow joint: When Sanda athletes do flat hooks, the athlete's elbow joint may be considered as rotation around the centroid axis, in the meantime the axis through the elbow joint and the axis of the athlete's body are similarly parallel, as shown in Figure 4.

Figure 4 shows the moment of inertia I_2 of the athlete's forearm: $I_2 = I_C + md^2$

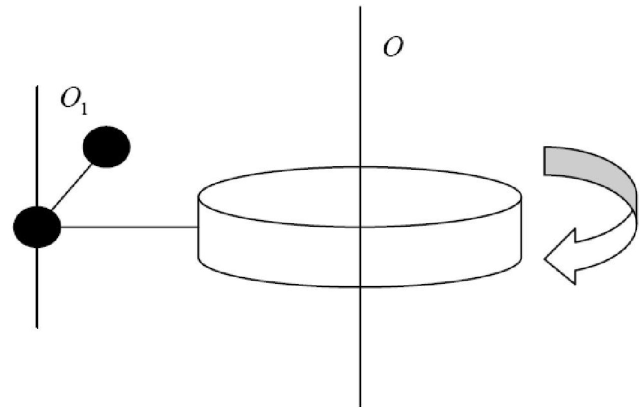

Figure 4 : Front view of players' rotation

When Sanda athletes do flat hook, left upper arm will produce a combined external torque M_1 in rotation driven by the shoulder joint, the formula is as follows $M_1 = \phi_1 \bullet I_1$.

Where ϕ_1 is the angular acceleration of the left upper arm, the rotational inertia of the left upper arm is I_1. Now the left upper arm and left forearm are seen as two cylindrical rigid bodies; then the moment of inertia I_1 of the left upper arm is: $I_B = \frac{m_1 r_1^2}{2}$

Where r_1 is the radius of the left upper arm, m_1 is the mass of the left upper arm, the angular acceleration ϕ_1 of the left upper arm is $\phi_1 = \frac{dw_1}{dt} = \frac{d^2\theta_1}{dt^2}$

Left forearm also produces an initial angular velocity in addition to an angular acceleration during the flat hook action, namely the angular velocity of the left upper arm is ϕ_1, so that the angular velocity ϕ_2 of the left forearm is $\phi_2 = \frac{dw_2}{dt} + \frac{dw_1}{dt} = \frac{d^2\theta_2}{dt^2} + \frac{d^2\theta_1}{dt^2}$, the rotational energy of the athletes is $E_k = \frac{1}{2}\sum_i m_i v_i^2 = \frac{1}{2} I\omega^2$:

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Flat hook data analysis of Sanda athletes

There are 16 elite male Sanda athletes from sports school, and TABLE 1 shows the basic situation of the athletes.

Now let the 16 outstanding athletes do warm up exercises for $15\,\text{min}$, later on attach stress sensor board on the athlete's whole body, search generated data when athletes do flat hooks and import it into three-dimensional coordinates, use Visual3 D software to conduct statistical analysis and smooth treatment. Then according to the mechanics formula $F = \sqrt{x^2 + y^2 + z^2}$, calculate the joint force of athlete's left foot and right foot together, draw the graph of the joint force, find out the time for lower limb force to the maximum value and the strength index when the athletes do flat hooks. In order to optimize the effect of athletes' body weight on the data record, so carry through the optimization process on all the following data that is related to the strength by using the body weight ratio, that is: $G = F_V(N)/9.8(N/kg)/G_1$

Related velocity data of athletes are obtained; i.e. the time of the athletes' each node reaches the maximum speed in the three-dimensional coordinates and the maximum speed, the formula is $V = \sqrt{x^2 + y^2 + z^2}$

Draw the speed change curve, obtain the internal rotation time of the forefoot and the rear foot from the athlete's lower limb force to athletes punch out, and get the time point at the forefoot landing moment from the lower limbs force and before the punches. The results obtained are represented in the form of $mean \pm SD$. Then conduct independent sample test $(P < 0.01)$ on the ratio of the strength of the left foot and the right foot and the athletes' weight, the time for the athletes' lower limbs to reach the maximum force, the ratio of the strength parameters and athletes' weight. And then it carries through correlation analysis on the relationship between these above parameters and the athlete's punch speed, fits it with the curve parameters of significant correlation, and then conducts regression analysis $(P < 0.01)$ on the parameter with the highest similarity. The following

TABLE 1 : Athletes' basic physical condition

The total number of people	Age	Training period	Posture	Height(m)	Body weight (kg)
16	17.5 ± 2.5	3.60 ± 1.7	Positive 12 Negative 4	1.68 ± 0.09	57.2 ± 4.1

is the calculation method for the extreme value of the quadratic equation, when $X = -b/2a$, Y has an extreme point, namely:

$$Y = (-b^2 + 4ac)/4a$$

Figure 5 shows the test results of the punches kinetics and the reaction on athletes by the ground when the athletes do flat hook.

Figure 5 shows that when the athletes do the hooks, the time point when the left foot rotates inward before punching out is the start time of the left foot's active force. At the landing moment of the right foot the strength of the lower limbs increases from zero, and the point is the starting time for the right foot to take the initiative to send the force. By combining with the force of left foot and right foot - time curve, we can see that when the athletes' legs carry through active force, and it can achieve the maximum value in a very short period of time; and the maximum data points of the legs are the end points of the active force. TABLE 2 shows the relationship between the above related parameters and fast strength.

The relationship between the fast strength and the various parameters of athlete's left foot and right foot is normally distributed through test. For the kinematics study of athletes' body, the average maximum speed of athletes' punches is $6.69 \pm 1.089\, m/s$. The correlation

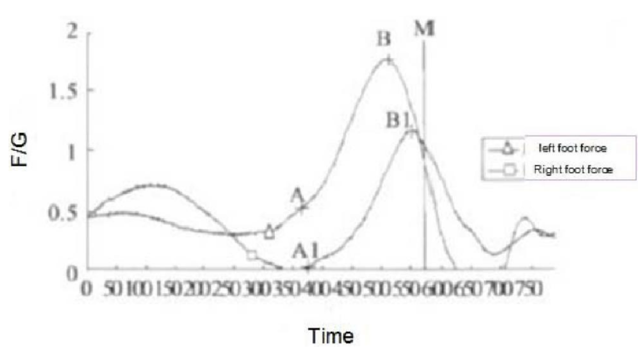

Figure 5 : The strength and weight ratio- time curve of athletes' left foot and right foot

between the strength parameters and punch speed of the left foot and the right foot is more significant, and the ratio of left and right foot's strength and athletes' weight, the time when the strength of athletes' lower limbs reaches the maximum, and the ratio of the strength parameters and athletes' weight also show a significant correlation. TABLE 3 shows the correlation between fast strength and punch speed of athlete's left foot and right foot.

By regression analysis, the ration of the left foot and right foot's maximum strength and weight, the ratio of fast strength parameters and weight, the linear relationship fitting of the punching is the closest, and the positive correlation is extremely significant; the time of the right foot reaches the maximum and punch speed has a quadratic functional relationship, and the extreme value of the right foot is $x = 0.204, y = 5.643$, the extreme value of the left foot is $x = 0.189, y = 5.587$. TABLE 4 shows the regression analysis table of the fast strength and punch speed of athletes' left foot and right foot.

TABLE 2 : Relationship between the fast strength and the various parameters of athlete's left foot and right foot

Parameter	The maximum strength value/weight	The time of the maximum strength(ms)	Fast strength index/weight
Left foot	1.706 ± 0.395	0.156 ± 0.038	10.12 ± 6.564
Right foot	1.845 ± 0.410	0.146 ± 0.036	13.077 ± 6.618

TABLE 3 : Correlation between fast strength and punch speed of athlete's left foot and right foot

Parameter	Maximum strength/weight of the right foot	The time of the right foot reaches the maximum (ms)	Fast strength/weight of the right foot	Maximum strength/weight of the left foot	The time of the left foot reaches the maximum (ms)	Fast strength/weight of the left foot
The correlation coefficient	0.905^{**}	-0.765^{*}	0.857^{**}	0.901^{**}	-0.744^{*}	0.893^{**}
value p	< 0.01	< 0.01	< 0.01	< 0.01	<0.01	<0.01

TABLE 4 : The regression analysis results of the fast strength and punch speed of athletes' left foot and right foot

Independent variable	n	Equation	F	T	P
Maximum strength/weight of the right foot	16	$Y = 2.04x + 2.11$	122.150	11.101	0.001
The time of the right foot reaches the maximum	16	$Y = 255\times 2 - 104x + 16.6$	15.541		0.000
Fast strength/weight of the right foot	16	$Y = 0.015x + 5.21$	60.744	7.801	0.000
Maximum strength/weight of the left foot	16	$Y = 2.24x + 2.41$	68.210	8.223	0.000
The time of the left foot reaches the maximum	16	$Y = 290\times 2 - 114x + 16.7$	14.011		0.001
Fast strength/weight of the left foot	16	$Y = 0.144x + 4.84$	44.980	6.733	0.000

CONCLUSIONS

Firstly, this paper conducts the mechanical analysis and dynamic analysis on the upper body and left and right arms of Sanda athletes when do flat hooks, obtains the potential energy produced by the various parts of the body when Sanda athletes do flat hooks. Then it analyzes that when the athletes do flat hooks, the correlation between the strength parameters and the punch speed of the left foot and right foot is more significant; the ratio of the strength of the left foot and right foot and the athlete's body weight, and the time for the left foot and right foot to reach the maximum strength has quadratic function relationships with the punch speed, the extreme value of the right foot is $x = 0.204, y = 5.643$, and the extreme value of the left foot is $x = 0.189, y = 5.587$. And as can be seen from the results, athletes' enhancing the strength and force speed when pedaling the ground in training, and shortening the force time are in favor of the punch speed of hooks.

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