ISSN : 0974 - 7435 Volume 10 Issue 3

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(3), 2014 [532-536]

Study of whip leg effects based on biomechanics and its application

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ABSTRACT

Make Chinese Sanda athletes to improve self skills effectively, this paper results in potential energy generated by whipping legs, by analyzing mechanical and dynamic relationships. Besides, propose the angular velocity of left thigh depends on hip joint angular velocity and waist speed while whipping leg, the angular velocities of knee joints and left thigh decide angular velocity of calf. Diving buckling degree of left thigh and left calf in preparation must be less than 45°and keep the angular velocity of calf greater than that of thigh to help accelerate knee joint. In the whip-leg stage, folding legs reduces inertia momentum, increasing angular velocity of knee joints effectively. Besides, it helps contract muscles, to keep best state to generate strength of legs and increase contract speed. In the whipping leg model, the principle conforms to momentum principle. Athletes can increase momentum of knee joints through braking effect of knee joints, then transferring to hip joints, to get end accelerations. The results provide the practical advice for athletes.

KEYWORDS

Sanda whip leg;
Biomechanics;
Mathematical model;
Rigid body motion.

INTRODUCTION

With Chinese five-thousand-year history, martial arts are more extensive and profound, which is progressing as society develops. The original name of sanda is sanshou, which is the martial arts crystallization[1]. It comes from primary society, as a self-protection method for resisting animals, hunting for food and various combats[2-5]. The basic motion of sanda is the high-level abstraction of universality of specific forms after arranging and abandoning, which includes straight line type and arc type[6-8]. In 1979, the enthusiasm was stimulated again, modeling as a modern competitive sport, the central government sports commission built training trial sites in some sports colleges such as Zhejiang, Bejing and Wuhan, etc. In 1982, China made sanda competition rules[9-11]. After then, China holds national martial arts confrontational projects exhibition games each year, insisting "positive, stability". Sanda is developing rapidly.

There are two motion forms, straight line and arc. Fist position mainly includes whipping, rushing and lifting. Leg skills mainly include kicking, pedal, whisk, whip, swing and hook. However, melee wrestling mainly breaks gravity center and circles, with no holding and velocity, includes clip play fall and take that fall. The defense includes "no touch defense" and "touch defense". Traditional titled form is used. The person who falls out of arena loses. The competition system is best of three sets. Chinese sanda has strong antagonism, which is different from taekwondo, western boxing, Muay Thai and judo. Muay Thai mainly includes fierce forms such as elbowing and knee attack. Judo mainly only includes trip, capturing and fall. Most of sanda athletes have high-level martial morality. During the competition, the elbowing, knee attack and joints attack are banned. The attack to neck, crotch and after brain is also banned. Sanda only includes beat near, kick far and wrestle body contact. The athletes have to roar loudly and fearfully to generate imposing manner. Relative researches indicate, under the state of no load, by self roaring, 10% muscle can increase 9% contract velocity, and the increasing effect will be more obvious under loads, about 14%. Therefore, the athletes roar each other in the competition. The legs include just kick, side kick, sweeping and whip leg, etc.

This paper studies whipping leg, which has fast speed, fine attacking effect and fine precision.

MODELING AND SOLVING

Basic procedures of whipping leg

While whipping leg, firstly, left knee bends slightly. Move gravity center to right leg. Then bend knees and lift to upper body. Turn left legs and adduct left knee slightly. Turn left calf outside. Relax ankle and lift knee to keep calf from outside to the top. Left knee generate strength suddenly and strikes to the internal front direction. Flat feet and strike legs sides. Finally keep basic competitive mode. Figure 1, Figure 2 shows the just and side whipping leg.

Dynamic analysis of whipping leg

While whipping leg, athletes have to bend knee and lift, turn left calf outside slightly, lift knee and make calf from outside to the top, generate strength and kick to internal front direction, and flat feet to side kick leg. The process can be seen as the rotation problems of two rigid bodies along a fix axis, shown as Figure 3.

A resultant applied force M_1 generates from the rotary process of left thigh forced by hip joints. The formula is shown as follows: $M_1 = \beta_1 \bullet I_1$

Of which, β_1 is angular acceleration of left thigh, I_1 is rotary momentum of left thigh. Consider left thigh gree model rotary around hip joint and knee joint, shown as Figure 4.

In Figure 4, N is the body, which is considered as rigid body. Thigh and calf are $oo_1, o_1 p$ respectively, whose lengths are l_1, l_2. Point o is hip joint. The anatomic angle of thigh and calf are α_1, α_2 respectively.

Build a stationary reference system as earth, the relative angular velocities of left thigh and calf are $\dot{\theta}_1$ and $\dot{\theta}_2$, the velocity of hip joint $\dot{\alpha}_2$ is:

$$\dot{}_2 = \dot{\theta}_2 - \dot{\theta}_1$$

The formula above shows, while whipping leg, the far angular velocity depends on near angular velocity and angular velocity of node, which is the angular velocity of calf depending on angular velocities of thigh and hip joints.

Figure 5 is the 3-dimentional vector figure for whipping leg, of which both hip joint o and knee joint o_1 have motion of thigh and calf on joints should be analyzed. It equals to vector multiplication of $\dot{\alpha}_1$ and $\vec{L}_2$, which is $\dot{\alpha}_1 \times \vec{L}_2$. According to vector principle, get:

$\bullet \quad \dot{}_{1}\ \vec{}_{1}\ \dot{}_{2}\ \vec{}_{2}\ \dot{}_{1}\ \vec{}_{2}$

According to effective allocation rate, get:

$\bullet \quad \dot{}_{1}(\vec{}_{1}\ \vec{}_{2})\ \dot{}_{2}\ \vec{}_{2}$

After simplifying: $\bullet \quad \dot{}_{1}(\vec{}_{1}\ \vec{}_{2})\ \dot{}_{2}\ \vec{}_{2}$

Of which $\dot{P}_G$ is position vector of point p in the reference system, also providing function for parameters of hip and knee joints and kinematic chain. Cross product $\vec{}_G \times \dot{\alpha}_1$ is velocity of point p generated by hip joints o, and cross product $\dot{\alpha}_2 \times \vec{L}_2$ is velocity of point p generated by knee joints o_1.

To better describe the relationship between velocity of point p and various joints, the relation between angles of joints and position of point p in Figure 5 is shown as follows:

$$\begin{cases} = \quad + \quad + \\ = \quad + \quad + \\ = \quad + \quad \sin(\quad + \quad) \end{cases}$$

Divide angles of node into infinite small displacement, solve the derivation of the formula above, and get:

$$\begin{cases} \frac{}{} \quad \frac{}{} \\ \frac{}{} \quad \frac{}{} \\ \frac{}{} \quad \frac{}{} \end{cases}$$

Write the formula above in matrix form:

$$\begin{pmatrix} \frac{}{} & \frac{}{} \\ \frac{}{} & \frac{}{} \\ \frac{}{} & \frac{}{} \end{pmatrix}$$

maximum. Hence, diving buckling degree of left thigh and left calf in preparation must be less than 45°, and the alternative velocities of anatomy angles of left thigh and left calf should be great, conforming to muscle mechanics. If the diving buckling degree of left thigh and left calf is too big, the muscle will be relaxant due to time contract. When α_1, α_2 meets $45^\circ < \ {}^{1} + \ {}^{2} < 90^\circ$, $0 < \dot{}_1 < \dot{}_2$, $\dot{\alpha}_1$ and $\dot{\alpha}_2$ increase. Besides the alternative ratio of anatomy angle of left thigh and calf in unit time is the maximum, such value should also greater than the alternative rate of angle of thigh. While whipping leg, it forced by three forces, which is counterforce from ground, friction and stress of joints. In the preparation stage, all the velocities are zero and the forces of calf are on the balance. In the kick stage, the muscles are stimulated, increase the force on ground suddenly and break the balance. The velocities of various joints are changed so that the angular velocity of leg is changed. Due to transferability of rigid body, when the kicking leg lifts from the ground, the angle between thigh and calf is nearly180°. The force transfers to thigh along the function line. However, due to the connection between thigh and calf, the force will be decreased. Therefore, the angular velocity of calf greater than that of thigh is better for accelerating knee joint.

CONCLUSION

By analyzing the mechanical relationship and dynamic relationship in whipping leg, the potential energy generated is solved. Besides, this paper results in the angular velocity of left thigh depends on angular velocity of hip joint and velocity of waist, the angular velocity of calf depends on angular velocity of knee joint and left thigh. The Diving buckling degree of left thigh and left calf in preparation must be less than 45° and the angular velocity of calf greater than that of thigh is bet-