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Research Article

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The dynamics model and application study of high kick in cheer aerobics

Haiyan Li

Department of Physical Education, Inner Mongolia Agricultural University, Huhhot, Inner Mongolia, China

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ABSTRACT

With the development of the society, Cheer aerobics develop rapidly and also get many companies' attention. In order to let the ordinary people learn the Cheer aerobics well in a healthy and scientific way, this passage has carried on studying the High kick of Cheer aerobics, and get the moment of inertia when the Cheer aerobics athletes high kick, what's more, we also find out the velocity relationship of athletes' legs and hips, knees and ankles according to analyzing the Dynamics. And get to know the potential energy and kinetic energy will be produced when the Cheer aerobics athlete's high kick, that is to say the athletes can effectively increase the momentum of knee joint by the braking of the hip joint. Similarly the athletes braking the momentum of knee joint and transfer it to ankle joint again to accelerate the ankle joint. So that we get the conclusion that it is more helpful to accelerate the knee joint if the calf of the angular velocity is larger than the thigh of the angular velocity and we can also find out that to the accelerate the knee joint, Cheer aerobics athlete's need to accelerate out speed of calf legs when they high kick to make the calf of the angular velocity is larger than the thigh of the angular velocity. As a result, it may hurt the ankle joint, knee joint as well as thigh because of the high speed of the ankle joint and the short of buffer time. But comparing with the ankle joint, the speed of the knee joint and thigh is small and has a long buffer time so the damage rate can be slightly lower.

Keywords: Moment of inertia of the analysis, the momentum analysis, dynamic analysis, the momentum transfer, biomechanics.

INTRODUCTION

Cheer leading, Chinese named LALA gym, Cheer means cheering, come on. So cheer leading appearing in the early tribal rituals, which aimed at encouraging or incentive to the warriors of war or hunting, with the meaning of hoping the warriors can triumph at the same time. However Cheer leading officially became a sports project appeared in the one hundred years ago in the United States, throughout the various groups of competitive sports in the United States. Cheer leading now turned into a very popular sport from the just cheering. Because Cheer leading consists of exercise, dance, music, fitness, entertainment, and mainly in the form of collective sports, so the Cheer leading has a strong universality which let it develop rapidly. Cheer leading belongs to the scope of the aerobics, but Cheer leading is comparatively easier than the aerobics, so it appears mostly as the performance of a team during half-time interval in the ball games and other games. But with the development of the times and the improvement of living standards, Cheer leading gradually becomes a project to make the game

Because the Cheer leading has the high effect of health fitness, body building and entertainment and other practical value, it is favored by more and more people with more and more material security times, which also catch the attention of varieties of ages of consumers and many television stations have also made some feature programs which take competition, universal as its contents, and get many companies' attentions as well. Modern cheer leading combined with dance, slogan, and partners' stunt actions and cooperate with the music, garment, team changes, and marked items as well, they work as teams to abide the rules of the game, which also known as competitive cheerleading. Cheer leading commonly used the styles of hand are separated type and combined type, ballet hand type, punch, palm and Spa cheer leading, Spanish dance hand type, etc. It absorbed and developed mostly from ballet and modern dance, disco. And every other part of the action of the cheer leading is similar to aerobics its basic form is stretch, bend, turn around, and placed, lift and vibration, which show the wavy movement, swinging, flex, swivel, round ring, leapfrog, dance and so on. In this article, we carry on analyzing and studying the high kick in leg movements of cheer leading

2. The establishment of the model and solution

Cheer leading athletes need to keep upright, waist, and then the right foot (left foot) ground to move the center of gravity to left foot (right), her hands rested on her hips or lift, the left leg (right leg) to hip for axis on the knees; Then deep hip to knee up to chest, round the knee joint and make the left (right) leg straight up, and finally to lift the right leg unbend above his head, finally back your left leg (right) when they high kick. Figure 1 is the whole process of cheer leading high kick.

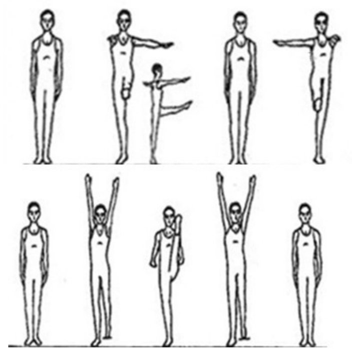

Figure 1: Cheer leading high kick schematic diagram

2.1 Dynamics analysis of Cheer leading high kick

Moment of inertia of refers to the production of the measure of the inertia when a rigid body move round the axis during the fixed axis rotation, which is only related to the rigid bodies' shape, quality, and the location of the axis, and has nothing to do with the parameters such as angular velocity. When cheer leading athlete does kick jump, they need to let the body upright, use the single leg jump, meanwhile, the other leg kicks out in straight forward, this process can regard the athletes' right leg as a rigid body which is doing the fixed axis rotation around the hip joint, Figure 2 is the Athletes' right leg rotation diagram.

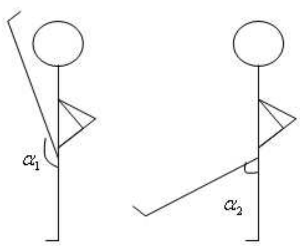

Figure 2: the schematic diagram of athletes' right leg's rotation of high leg lifts

Cheer leading athlete's moment of inertia is: $I = \Sigma M_i Q_i^2$

But due to the continuous of all parts of the body, we regard the cheer leading athlete's body as a rigid body of continuous distribution of quality, so that: $I = \iiint_v Q^2 dm = \iiint_v Q^2 \rho dV$

Among them M_i is the quality of all parts of the body, the distance of each part of the athletes to the axis is Q, The density of the human body is ρ . Cheer leading athlete's right leg rotation tensor $\overleftrightarrow{S}_c$ is: $\overleftrightarrow{S}_c = \iiint_v \rho(Q^2 \overleftrightarrow{E} - \vec{Q}\vec{Q})dV$ The radius vector expression of Athletes' arbitrary point on the body O is $\vec{Q} = Q_1 \vec{e}_1 + Q_2 \vec{e}_2 + Q_3 \vec{e}_3$;The product of two vectors is $\vec{Q}\vec{Q}$; Unit tensor of athletes' Body are : $\overleftrightarrow{E} = \begin{bmatrix} 1 & & \\ & 1 & \\ & & 1 \end{bmatrix}$, is Unit orthogonal curvilinear frame.

2.2 The torque equation of rotation tensor of Cheer leading high kick

Joint torque vector of Cheer leading high kick is $\Sigma \vec{j}_c$, $\vec{\omega}$ is the angular velocity of the Athletes in the inertial vector of dynamic system, The angular acceleration vector is $\vec{\theta}$, so that the rotation tensor torque equation of Cheer leading high kick is: $\Sigma \vec{j}_c = \overleftrightarrow{S}_c \bullet \vec{\theta} + \vec{\omega} \times \overleftrightarrow{S}_c \bullet \vec{\omega}$

Now we project the torque equation to the three coordinate system x, y, z on the shaft and get the torque equation of the athletes' right leg in the every axis direction. When the athlete is doing high kick, the external torque of right thigh rotation N_1 is: $N_1 = \chi_1 \bullet I_1$

Among them χ_1 is the angular acceleration of right thigh, the rotational inertia of the right thigh is I_1 . And: $I_1 = \frac{M_1 R_1^2}{2}$ R_1 is the radius of the right thigh, M_1 is the quality of right thigh, The angular acceleration of right thigh χ_1 is: $\chi_1 = \frac{dw_1}{dt} = \frac{d^2\alpha_1}{dt^2}$.

Since the initial angular velocity of the right lower leg is the angular velocity of right thigh χ_1, so that the angular velocity of the right lower leg χ_2 is : $\chi_2 = \frac{dw_2}{dt} + \frac{dw_1}{dt} = \frac{d^2\alpha_2}{dt^2} + \frac{d^2\alpha_1}{dt^2}$

Now we regard of the cheer leading athletes' right legs as two rigid bodies and build the hip joint and knee joint up to three Degrees of freedom model, which is shown in Figure 3.

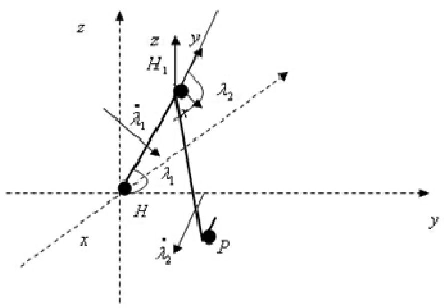

Figure 3: Two schematic diagram of rigid body with three degrees of freedom of sportsman' right leg

In figure 3, point H is hip joint, H_1 is knee joint, length of thigh and calf respectively is h_1, h_2, the anatomical angle is λ_1, λ_2. And H and H_1 both is three degrees of freedom, and three dimensional vector is $\dot{\lambda}_1, \dot{\lambda}_2$.

As for the reference system on earth, $\dot{\phi}_1$ and $\dot{\phi}_2$ are angular speed with respect to the reference system of athletes' thigh and calf. Speed of knee joint is $\dot{\lambda}_2$, and $\dot{\lambda}_2 = \dot{\phi}_2 - \dot{\phi}_1$.

When cheer leading athletes are doing high kicks, the angular speed of thigh, calf and knee joint all can affect angular speed of ankle P. Because thigh and calf are rotatable, we can know that when knee joint H_1 is doing circular motion, it can drive calf do translation and rotation with respect to coordinate system $H_1 - xyz$. Rotation and translation are relatively independent, so they will not affect another' motion vector of hip joint and knee joint and angular speed of calf. Ankle P' angular speed is relative to its speed with respect to inertial coordinate and line speed of knee joint with respect to coordinate system, i.e. $\vec{C}(\vec{H}_1)_G = \dot{\lambda}_1 \times \vec{V}_1 = \dot{\lambda}_1 \times \vec{V}_1$, $C(\vec{P})_L = \dot{\lambda}_2 \times \vec{V}_2$, in the formula, $\vec{C}(\vec{H}_1)_G$ is knee joint' velocity vector relative to coordinate system. $C(\vec{P})_L$ is speed of P with respect to H_1. $\dot{\lambda}_1, \dot{\lambda}_2$ respectively is angular speed of hip joint H and knee joint H_1. $\vec{V}_1$ is position vector from hip joint to knee joint. $\vec{V}_2$ is position vector from knee joint to ankle P.

In order to get speed $\dot{p}_G = \vec{C}(\vec{P})_G$ of ankle P with respect to earth, we must get the influence of local motion of thigh and calf on joints at first of all. According to vector theorem, we can see $\dot{P}_G = \dot{\lambda}_1 \times \vec{V}_1 + \dot{\lambda}_2 \times \vec{V}_2 + \dot{\lambda}_1 \times \vec{V}_2$, $\dot{P}_G = \dot{\lambda}_1 (\vec{V}_1 + \vec{V}_2) + \dot{\lambda}_2 \times \vec{V}_2$. After simplifying: $\dot{P}_G = \vec{P}_G \times \dot{\lambda}_1 + \dot{\lambda}_2 \times \vec{V}_2$. Position vector of ankle in the coordinate system is $\dot{P}_G$. Vector product $\vec{P}_G \times \dot{\lambda}_1$ is the speed that hip joint makes ankle make. In the same way, vector product $\dot{\lambda}_2 \times \vec{V}_2$ is speed that knee joint makes ankle make.

To further clearly describe the speed relationship among hip joint, knee joint and ankle, the relationship of the angle of hip joint and knee joint and the position of ankle in figure 3 can be writed as following:

$$\begin{cases} x_p = V_1 \cos \lambda_1 + V_2 \cos(\lambda_1 + \lambda_2) \\ y_p = V_1 \sin \lambda_1 + V_2 \sin(\lambda_1 + \lambda_2) \\ z_p = V_1 \cos \lambda_1 + V_2 \sin(\lambda_1 + \lambda_2) \end{cases}$$

To do differential angle of hip joint and knee joint, the relationship with position vector of ankle can be differentiate from the above formula:

$$\begin{cases} dX = \frac{\partial X(\lambda_1, \lambda_2)}{\partial \lambda_1} d\lambda_1 + \frac{\partial X(\lambda_1, \lambda_2)}{\partial \lambda_2} d\lambda_2 \\ dY = \frac{\partial Y(\lambda_1, \lambda_2)}{\partial \lambda_1} + \frac{\partial Y(\lambda_1, \lambda_2)}{\partial \lambda_2} d\lambda_2 \\ dZ = \frac{\partial Z(\lambda_1, \lambda_2)}{\partial \lambda_1} + \frac{\partial Z(\lambda_1, \lambda_2)}{\partial \lambda_2} d\lambda_2 \end{cases}$$

To diverse this into matrix form:

$$\begin{pmatrix} dX \\ dY \\ dZ \end{pmatrix} = \begin{pmatrix} \frac{\partial X(\lambda_1,\lambda_2)}{\partial \lambda_1} & \frac{\partial X(\lambda_1,\lambda_2)}{\partial \lambda_2} \\ \frac{\partial Y(\lambda_1,\lambda_2)}{\partial \lambda_1} & \frac{\partial Y(\lambda_1,\lambda_2)}{\partial \lambda_2} \\ \frac{\partial Z(\lambda_1,\lambda_2)}{\partial \lambda_1} & \frac{\partial Z(\lambda_1,\lambda_2)}{\partial \lambda_2} \end{pmatrix} \begin{pmatrix} d\lambda_1 \\ d\lambda_2 \end{pmatrix}$$

According to the nature of the matrix and the cross product method, we can write above formulalike the following: $d\vec{P}_G = \vec{Q}\, d\,\vec{\lambda}$. In that formula, $\vec{Q}$ is

$$\vec{Q} = \begin{pmatrix} \frac{\partial X}{\partial \lambda_1} & \frac{\partial X}{\partial \lambda_2} \\ \frac{\partial Y}{\partial \lambda_1} & \frac{\partial Y}{\partial \lambda_2} \\ \frac{\partial Z}{\partial \lambda_1} & \frac{\partial Z}{\partial \lambda_2} \end{pmatrix}$$

$\vec{Q}$ is the differential relationship between the infinitesimal displacement of joint angular displacement and ankle in the current structure. Bring the matrix relation into the above formula, we can see:

$$\frac{d\vec{P}_G}{dt} = \vec{Q}\frac{d\vec{\lambda}}{dt} \quad \text{or} \quad \vec{P}_G = \vec{Q}[\dot{\lambda}_1, \dot{\lambda}_2]^T$$

Bring it into the relative velocity formula of ankle, we can get:

$$\dot{P}_G = \begin{pmatrix} \frac{\partial X}{\partial \lambda_1} & \frac{\partial X}{\partial \lambda_2} \\ \frac{\partial Y}{\partial \lambda_1} & \frac{\partial Y}{\partial \lambda_2} \\ \frac{\partial Z}{\partial \lambda_1} & \frac{\partial Z}{\partial \lambda_2} \end{pmatrix} [\vec{\lambda}_1, \vec{\lambda}_2]^T \dot{\lambda}_1 + \dot{\lambda}_2 \times \vec{V}_2$$

From the analysis we can know when cheerleading athletes are doing high kicks, in order to make motion coherence good, they must fast the foot speed. Only in this way, P_G can get maximum of velocity projection in the z direction, and only when λ_1, λ_2 is satisfied the constraint condition $40^\circ < \lambda^1 + \lambda^2 < 90^\circ$ and $0 < \dot{\lambda}_1 < \dot{\lambda}_2$, speed of ankle P can get maximum on vertical plane. This requests the flexion degree of athletes' left thigh calf cannot be more than 40°, and the shifting time must be short when athletes are doing preparation of high kicks. If leg' submergence flexion degree is too much, the muscles can be loose because of the shrink of long time on muscles.

When λ_1, λ_2 meet their constraint condition, with the increasing of $\dot{\lambda}_1$ and $\dot{\lambda}_2$, the change rate of anatomical angle of thigh and calf in unit time when athletes are doing high kicks will requested to reach maximum, and during this time, the change rate of anatomical angle of calf must be bigger than thigh'. According to can transfer theorem of rigid body, we can see that when right leg leave ground, the angle between thigh and calf is 180°, and power will convey along thigh axis to calf. But because the thigh and calf are connected, so that the power will lose during the transfer process. So the angular speed of calf bigger than thigh' is more benefit to the acceleration of knee joint. And from the mechanical analysis of athletes' high kicks, we can see that when athletes are doing high kicks, they need to speed up calf' foot speed to make the calf' angular speed bigger than thigh' in order to fasten knee joint' acceleration. In that athlete' ankles, knee joints and thighs will be injured because the ankles' speed is too much and the buffer time is too short when athletes reach the ground. But as far the speed of ankles, knee joints and thighs era relatively little, and the buffer time is much longer, so the rate of injury will be less.

CONCLUSION

Through the research, this text get right leg' moment of inertia when athletes are doing high kicks, and know the speed relationship among athletes' thigh, calf, hip joint, knee joint and ankle through analysis of thermodynamics and kinetics. And we already have known that when athletes are doing high kicks, the right leg produces potential energy and kinetic energy i.e. athletes can increase knee joint' kinetic energy by hip joint' affective braking effect. In the same reason, through knee joint' braking effect to transfer momentum to ankle to get the result to fasten ankle. So that this text knows that angular speed of calf should be bigger than thigh', and it is benefit to knee joint' acceleration. And we can find that when cheerleading athletes are doing high kicks, they should speed up calf' foot speed to make the angular speed of calf bigger than thigh' in order to drive knee joint' acceleration. In those athletes' ankles, knee joints and thighs will be injured because the ankles' speed is too much and the buffer time is too short when athletes reach the ground. But as far the speed of ankles, knee joints and thighs era relatively little, and the buffer time is much longer, so the rate of injury will be less.

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