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Research Article

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Analytic hierarchy process-based dunk technical exertion affected physical quality weight analysis

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ABSTRACT

The paper adopts mechanical knowledge, mainly analyzes dunk technique, when basketball player takes-off, it should increase himself rotational angular speed, let legs arrive at flat and straight, make gravity center and body rotational axis come to terms so that it can reduce rotational inertia and further arrives at increasing rotational angular speed effects, and, at the same time of taking-off, twists upper body also can continue to increase self-rotational angular speed, let dunk to be fiercer. Establish analytic hierarchy process model, according to weight result, it is clear that good awareness accounts for 43.7% of basketball player dunking required competence, when basketball player uses dunk technique, it requires that athlete should firstly possess good awareness, secondly, athlete should be adept in dunk technique, and the third is self-physique requirement.

Key words: moment of momentum theorem, geometric model, analytic hierarchy process, physiological function

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INTRODUCTION

Basketball appeared with special way in China in 100 years ago, and meanwhile it also attracted public attentions, because basketball had its own competitiveness, entertainment and appreciations, basketball competitive sports were paid widely attentions to, Chinese basketball market also got internationalized changes, and, according to statistics, Chinese basketball population nearly occupied 19% of Chinese total population [1-5]. It can be said that Chinese basketball development is good, step is stable.

Basketball started in 1891, it was created by American James Naismith, but rim height was 3.05m at that time, and then dunk technique not only could encourage morale of members inside field, similarly dunk could also take audience atmosphere to the climax [6-9]. Meanwhile, most internationally well-known NBA match, it emerged lots of outstanding basketball players, among these athletes, there were excellent dunk masters as well, such as 70s sky-hook Julius Erving, in 1987, Basketball player Jordan achieved the honor of “flying man”, he sprang up from throw line to single arm dunk [10-12].

In recent years, domestic researches about dunk technique are still little, though basketball technique also appears systematical research, it lacks of careful research, and lacks of exact strategy. The paper will combine with arms rotational inertia, and analyzes when basketball player dunks, hands joint mechanical movements, combines with shoulder joint, elbow joint mechanical analysis to research on dunk technique.

MODEL ESTABLISHMENTS

Arms rotational inertia calculation

By Lagrange equation， the paper gets restricted particle dynamical equation, from which，Lagrange function L is system kinetic energy K and potential energy P generated difference: $L = K - P$

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

System dynamics equation is:

In above formula $\dot{q}_i$ is corresponding speed, q_i is kinetic energy and potential energy coordinate, F_i is the i coordinate acting force, thigh and shank together with coordinate axis included angles are respectively θ_1, θ_2, lengths are respectively l_1, l_2, arms front and back gravity center position distances with elbow joint center and knee joint are respectively p_1, p_2, therefore it is clear that arms gravity center coordinate (X_1, Y_1) is:

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

Similarly, arms gravity center coordinate (X_2, Y_2) can also be solved. System kinetic energy E_k and system potential energy E_p expression is:

$$\begin{cases} E_k = E_{k1} + E_{k2}, E_{k1} = \frac{1}{2} m_1 p_1^2 \dot{\theta}_1^2 \\ E_{k2} = \frac{1}{2} m_2 l_1^2 \dot{\theta}_1^2 + \frac{1}{2} m_2 p_2^2 \left(\dot{\theta}_1 + \dot{\theta}_2\right)^2 + m_2 l_2 p_2 \left(\dot{\theta}_{01}^2 + \dot{\theta}_1 \dot{\theta}_2\right) \cos\theta_2 \\ E_p = E_{p1} + E_{p2}, E_{p1} = \frac{1}{2} m_1 g p_1 (1 - \cos\theta_1) \\ E_{p2} = m_2 g p_2 [1 - \cos(\theta_1 + \theta_2)] + m_2 g l_1 (1 - \cos\theta_1) \end{cases}$$

Write above formula as Lagrange function expression, by Lagrange system dynamics equation, it can get hip joint and knee joint moment M_h and M_k as:

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

In above formula D_{ijk} is as following result:

$$D_{111} = 0 \quad D_{222} = 0 \quad D_{121} = 0$$

$$D_{22} = m_2 p_2^2$$

$$D_{11} = m_1 p_1^2 + m_2 p_2^2 + m_2 l_1^2 + 2 m_2 l_1 p_2 \cos\theta_2$$

$$D_{12} = m_2 p_2^2 + m_2 l_1 p_2 \cos\theta_2 \quad D_{21} = m_2 p_2^2 + m_1 l_1 p_2 \cos\theta_2$$

$$D_1 = (m_1 p_1 + m_2 l_1) g \sin\theta_1 + m_2 p_2 g \sin(\theta_1 + \theta_2)$$

$$D_{122} = -m_2 l_1 p_2 \sin\theta_2$$

$$D_{211} = m_2 l_1 p_2 \sin\theta_2$$

$$D_{112} = -2 m_2 l_1 p_2 \sin\theta_2$$

$$D_{212} = D_{122} + D_{211}$$

$$D_2 = m_2 p_2 g \sin(\theta_1 + \theta_2)$$

Combine with theoretical formula, when analyze basketball dunking, hand part joint mechanical movement, combines with shoulder joint, elbow joint mechanical analysis to research on dunk technique.

Establish moment of momentum theorem model

When apply mechanical conservation law to solve problems, firstly it should c choose reasonable research objects, and make correct force analysis of researched objects, secondly on the basis of force analysis, refer to conservation law to check problem, and according to conservation law, it establishes equation and solves problems.

Set I to be one rigid body rotational inertia, suffered moment M effects, from which angular accelerated speed

β is constant, the rigid body at t_1 instant angular speed is ω_1, rigid body at t_2 instant angular speed is ω_2, it gets: $M = I\beta = I\frac{\omega_2 - \omega_1}{t_2 - t_1}$

Transform and get: $M(t_2 - t_1) = I(\omega_2 - \omega_1)$

When $M = M(t)$, it has: $M(t)(t_2 - t_1) = I(\omega_2 - \omega_1)$

It gets momentum formula, from which $M(t_2 - t_1)$ is impulsive moment, $I\omega$ is momentum, according to formula, it is clear that rigid body impulsive moment variable and momentum variable are equal.

In moment of momentum theorem, time and moment product is equal to impulsive moment that represents rotational accumulative effect under external moment effects. Angular speed and rotational inertia product is state when rigid body rotates. With external moment increasing and acting time enlarging, rigid body rotational state change will accordingly increase.

When human body exercises, human body generated rotational inertia is changing, due to rotational inertia changes, different moments rotational inertia is different, set t_1 moment rotational inertia is I_1, t_2 moment rotational inertia is I_2, therefore, above formula can be revised as: $M(t)(t_2 - t_1) = I_2\omega_2 - I_1\omega_1)$

To human body movement rules, it should meet: $I\omega = 0, \sum M\Box t = 0$

At this time, it enters into soaring phase, assume human body meets: $I_1\omega_1 + I_2\omega_2 = 0$

In addition, it should also meet that human body rotates around $I_1\omega_1$, so the movement form is lengthwise relative movement, during dunking process solve the sum of human body momentum to be 0, according to correlation rules, we are clear that human body will suffer ball exerted an reactive force that let people generate momentum, so that reduce dunking process strength size, so it is bad for dunking stability, but if during dunking process, due to body each part suffered active force effects, it causes rotational inertia increase and further will generate an advancing momentum effects, according to energy conservation law, we know that now human body similarly will generate an reactive force effects, so that human body moves relative to ball so that increase swinging distance and concentrate whole body strength to stroke.

In the whole dunking process, each limb will generate opposite directions but same size moment, and every pair can offset, when athlete lands, sole part rapidly lands to support the whole body, meanwhile it will occur to abdomen contracting, knees bending and others to buffer declining strength that makes preparations for next motions.

Air angular speed changes, in case that momentum remains unchanged, rotational inertia will reduce with angular speed increasing, when athlete takes-off and soars, athlete himself can further control rotational angular speed by changing his rotational inertia.

Twist dunk is smashing by changing upper body faced direction when athlete takes-off and strokes; when athlete takes-off, it should increase athlete himself rotational angular speed, so, athlete takes-off, legs arrive at flat and straight, let gravity center and body rotational axis come to terms so that can reduce rotational inertia, and further arrive at increasing rotational angular speed effects, and, at the same time of taking off, twist upper body can also continue to increase himself rotational angular speed let dunk more rapidly.

When athlete takes-off and arrives at top point, athlete should try to adjust body stability, let rotational angular speed try to reduce; then, athlete should raise legs backward, let gravity center to be far away from rotational axis. And arrive at stable dunking state.

Analytic hierarchy process model analysis

Establish hierarchical structure

Establish target layer, criterion layer and project layer relations.

Target layer: basketball player dunking required quality.

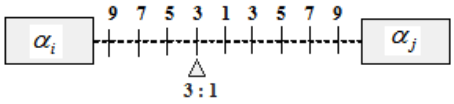
Criterion layer :(Project influence factor)

c_1 is speed 、c_2 is experience、c_3 is passing, dribbling experience、c_5 is cooperative ability

Project layer: A_1 dunk technique、A_2 self -physique、A_3 awareness

Construct judgment (paired comparison) matrix

With Figure 1 showed 1～9 scale table as evidence, it proceeds with weight analysis.



$$a_{ij}=3, a_{ji}=\frac{1}{3}$$

Figure 1: 1～9 scale graph

At first solve judgment matrix, according to above principle, reference 1～9 scale setting, and according to expert and author's experience and refers to lots of documents, it gets paired comparison matrix under four criterions that are respectively as Table 2-4.

Table 2: Comparison matrix

G	c_1	c_2	c_3	c_4
c_1	1	8	5	3
c_2	1/8	1	1/2	1/6
c_3	1/5	2	1	1/3
c_4	1/3	6	3	1

Table 3: Comparison matrix

c_1	A_1	A_2	A_3	c_2	A_1	A_2	A_3
A_1	1	5	1/5	A_1	1	3	3
A_2	1/5	1	1/5	A_2	1/3	1	3
A_3	5	5	1	A_3	1/3	1/3	1

Table 4: Comparison matrix

c_3	A_1	A_2	A_3	c_4	A_1	A_2	A_3
A_1	1	5	3	A_1	1	1/5	1/8
A_2	1/5	1	3	A_2	5	1	1/3
A_3	1/3	1/3	1	A_3	8	3	1

Hierarchical total arrangement

$$A=\begin{Bmatrix} 1 & 8 & 5 & 3 \\ 1/8 & 1 & 1/2 & 1/6 \\ 1/5 & 2 & 1 & 1/3 \\ 1/3 & 6 & 3 & 1 \end{Bmatrix}$$

$$\xrightarrow{\text{Column vector normalization}} \begin{Bmatrix} 0.603 & 0.470 & 0.526 & 0.667 \\ 0.075 & 0.059 & 0.053 & 0.037 \\ 0.121 & 0.118 & 0.105 & 0.074 \\ 0.201 & 0.353 & 0.316 & 0.222 \end{Bmatrix}$$

$$\xrightarrow{\text{Solve sum by line}} \begin{Bmatrix} 2.266 \\ 0.224 \\ 0.418 \\ 1.092 \end{Bmatrix}$$

$$\xrightarrow{\text{Normalization}} \begin{Bmatrix} 0.567 \\ 0.056 \\ 0.104 \\ 0.273 \end{Bmatrix} = W^{(0)}$$

$$AW^{(0)}=\begin{Bmatrix} 1 & 8 & 5 & 5 \\ 1/8 & 1 & 1/2 & 1/6 \\ 1/5 & 2 & 1 & 1/3 \\ 1/3 & 6 & 3 & 1 \end{Bmatrix}\begin{Bmatrix} 0.567 \\ 0.056 \\ 0.104 \\ 0.273 \end{Bmatrix}=\begin{Bmatrix} 2.554 \\ 0.225 \\ 0.422 \\ 1.110 \end{Bmatrix}$$

$$\lambda_{\max}^{(0)}=\frac{1}{4}\left(\frac{2.354}{0.567}+\frac{0.225}{0.056}+\frac{0.422}{0.104}+\frac{1.110}{0.273}\right)=4.073$$

$$w^{(0)}=\begin{pmatrix} 0.567 \\ 0.056 \\ 0.104 \\ 0.273 \end{pmatrix}$$

Similarly, it can calculate judgment matrix:

$$B_1=\begin{Bmatrix} 1 & 5 & 1/5 \\ 1/5 & 1 & 1/5 \\ 5 & 5 & 1 \end{Bmatrix}, B_2=\begin{Bmatrix} 1 & 3 & 3 \\ 1/3 & 1 & 3 \\ 1/3 & 1/3 & 1 \end{Bmatrix}, B_3=\begin{Bmatrix} 1 & 5 & 3 \\ 1/5 & 1 & 3 \\ 1/3 & 1/3 & 1 \end{Bmatrix}, B_4=\begin{Bmatrix} 1 & 1/5 & 1/8 \\ 5 & 1 & 1/3 \\ 8 & 3 & 1 \end{Bmatrix}$$

Corresponding maximum feature value and feature vector in successive are:

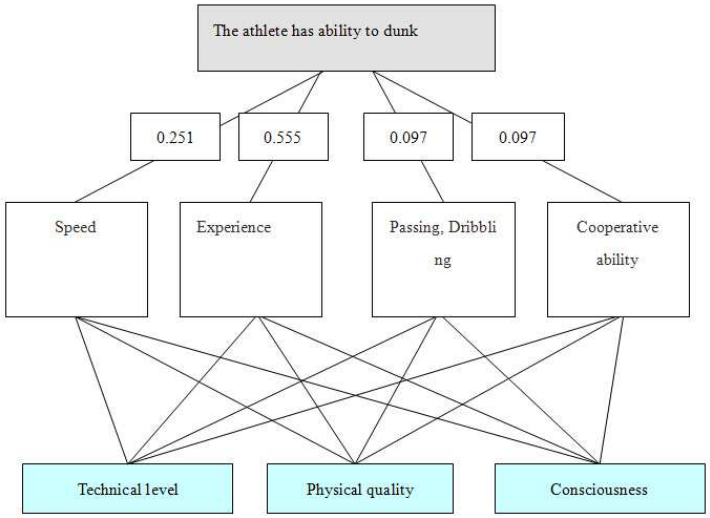
$$\lambda^{(1)}{}_{\max}=3.31, \omega^{(1)}{}_1=\begin{Bmatrix} 0.252 \\ 0.089 \\ 0.66 \end{Bmatrix}$$

$$\lambda^{(2)}{}_{\max}=3.12, \omega^{(1)}{}_2=\begin{Bmatrix} 0.575 \\ 0.286 \\ 0.139 \end{Bmatrix}$$

$$\lambda^{(3)}{}_{\max}=3.30, \omega^{(1)}{}_3=\begin{Bmatrix} 0.624 \\ 0.240 \\ 0.136 \end{Bmatrix}$$

$$\lambda^{(4)}{}_{\max}=4.05, \omega^{(1)}{}_4=\begin{Bmatrix} 0.185 \\ 0.240 \\ 0.575 \end{Bmatrix}$$

Utilize hierarchical chart drawing out calculation results from target layer to project layer, as Figure 2 show.



$$\begin{Bmatrix}0.258\\0.049\\0.637\end{Bmatrix},\begin{Bmatrix}0.875\\0.156\\0.186\end{Bmatrix},\begin{Bmatrix}0.674\\0.250\\0.136\end{Bmatrix},\begin{Bmatrix}0.455\\0.268\\0.575\end{Bmatrix}$$

Figure 2: Hierarchical structure chart

Calculation structure is as following:

$$\omega^{(1)}=(\omega_1^{(1)},\omega_2^{(1)},\omega_3^{(1)},\omega_3^{(1)}) =\begin{Bmatrix}0.624 & 0.185 & 0.252 & 0.575\\0.234 & 0.240 & 0.089 & 0.286\\0.136 & 0.575 & 0.66 & 0.139\end{Bmatrix}$$

$$w=w^{(1)}w^{(0)}$$

$$=\begin{Bmatrix}0.245 & 0.635 & 0.624 & 0.155\\0.058 & 0.286 & 0.250 & 0.270\\0.77 & 0.445 & 0.121 & 0.575\end{Bmatrix}\begin{Bmatrix}0.587\\0.0567\\0.145\\0.253\end{Bmatrix}=\begin{Bmatrix}0.332\\0.231\\0.437\end{Bmatrix}$$

According to weight result, it is clear when basketball player uses dunk technique, it is required that athlete should firstly possess good awareness, secondly, athlete should be adept in dunk technique, and the third is self-physique requirement.

CONCLUSION

The paper adopts mechanical knowledge, mainly analyzes dunk technique, he smashes by changing upper body faced directions, when basketball player takes-off, he should increase himself rotational angular speed, let legs arrive at flat and straight, make gravity center and body rotational axis come to terms so that it can reduce rotational inertia and further arrives at increasing rotational angular speed effects, and, at the same time of taking-off, twists upper body also can continue to increase self-rotational angular speed, let dunk to be fiercer.

From result, it is clear that good awareness accounts for 43.7% of basketball player dunking required competence, when basketball player uses dunk technique, it requires that athlete should firstly possess good awareness, secondly, athlete should be adept in dunk technique, and the third is self-physique requirement.

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