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The study of the biomechanics parameter effect to the serve and pass skill of volleyball players

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ABSTRACT

This essay systematically studied the volleyball serve and pass skill, and we used theories like differential equation and hydromechanics to show the inner principles that could be the best suitable way to higher the score make by the players in the volleyball serve process. And at the same time, we proved the way to combine the theory with the reality suits the volleyball development best by the way of experiment. This study will provide basis for the players and their coaches to master the right training scheme.

Keywords: biomechanics analysis, horizontal velocity, kinematics, vertical velocity

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INTRODUCTION

As early as hundreds of years ago, there is a new sport appeared in America --- the volleyball. And as the increasing of the undertake countries of the Olympics, the value of the sport is increasing as well, and the volleyball is also essential. Therefore, the intense degree of the volleyball match is also increasing. It is important to keep the players' health in a good condition, but to higher the score, the skill improvement is more significant.

At present, there are a lot of scholars made their studies of this sport, such as, Zhang Qinghua's analyze to the step forward spike skill of man, and put forward the spike movement could separate into three steps of isometric system, push off and buffer. The time-consuming of each step is the factor that influences the spike step, and he finally put forward that the major influential factor is the push off step. And He Ling's mechanics analyze to the spike skill of volleyball provided an important basis to the training of the players and their coaches in days to come.

This essay is just about the relevance study of the kinematics and the analysis of biomechanics in volleyball on these basic studies. We combined our study with reality to confirm it. And this study will make a positive effect on the development of volleyball sport.

1. The mechanics analysis model of the process of volleyball serve

The movement process of volleyball will be influenced by resistance, friction in the air and gravity. If we set v as the average speed when the volleyball moving forward, ρ as density, η as the coefficient of viscosity of the air, ω as the angular speed of spin, and r as radius of the ball, then we can get $v = 20m \cdot s^{-1}$, $r = 0.105m$, $\mu = 18.1 \times 10^6 Pa \cdot s$, $\rho = 1.205kg \cdot m^{-3}$ from experience. And according to the definition of the Reynolds number in hydromechanics, we can get:

$$\mathrm{Re} = \frac{\rho 2ru}{\mu} = 2.80 \times 10^{-5} \tag{1}$$

We use u as the relative speed between the volleyball to the air, and we can tell that the Reynolds number is less than 1 from the form above. Then we can use the Stokes theory to figure out the friction in the air against the volleyball as follow:

$$f = \frac{c\rho A v^2}{2} \tag{2}$$

We use S as the CAS of the ball, and c as the coefficient of friction in the form, we make:

$$k = \frac{c\rho S}{2} \tag{3}$$

Then:

$$f = kv^2 \tag{4}$$

We can get from the form above that the average speed and the friction in the air are in the proportional function relationship. The viscidity of the friction in the air made the ball spin in its movement, and that made the pressure difference on both sides of the ball. This made the ball moving toward the faster speed side of air flow, and the force is:

$$F = \frac{8\pi\rho\omega r^3 v}{3} \tag{5}$$

If:

$$G = \frac{8\pi\rho\omega r^3}{3} \tag{6}$$

Then:

$$F = Gv \tag{7}$$

According to the above, the direction of the volleyball movement will depart to the other side because of the existence of the Magnus force. The movement will make an arc, and so there will be different arcs when the player impacts the volleyball from different angles.

2.1 The analysis to the volleyball movement in using of the differential equation

Under the condition of not considering the influence of inner friction, the analysis to the volleyball movement in using of the differential equation is as follow:

$$2M\frac{dz}{dt^2} = Mg\ ,\quad M\frac{du}{dt} = -ku^2\ ,\quad M\frac{u^2}{R} = Gu \tag{8}$$

Deal with the forms above, we get:

$$\int \frac{du}{u^2} = -\frac{k}{M}\int dt \tag{9}$$

$$-\frac{1}{v} = -\frac{k}{M}t + C_1 \tag{10}$$

Substitute $t = 0$ and $u = u_0$ into the form above, then:

$$C_1 = -\frac{1}{u_0} \tag{11}$$

In that we have:

$$v = \frac{Mu_0}{M + ku_0 t} \tag{12}$$

And because of:

$$ds = udt$$

Then:

$$s = \int_0^r \frac{Mu_0}{M + ku_0 t} dt = \frac{M}{k} l_n \frac{M + ku_0 t}{M} \tag{13}$$

If we take $R = \frac{ds}{d\theta} = \frac{ds}{dt}\frac{dt}{d\theta} = v\frac{dt}{d\theta}$ substitute into $\frac{d\theta}{dt} = \frac{G}{M}$, then:

$$\theta = \int_0^\theta d\theta = \int_0^t \frac{G}{M} dt = \frac{G}{M} t \tag{14}$$

$$u_x = u\cos\theta = \frac{Mu_0}{M + ku_0 t} \cos\frac{G}{M} t \tag{15}$$

$$u_y = u\sin\theta = \frac{Mu_0}{M + ku_0 t} \sin\frac{G}{M} t \tag{16}$$

Because M is larger than $ku_0 t$, we can first ignore it, thus:

$$u_x = u_0 \cos\frac{G}{M} t \tag{17}$$

$$u_y = u_0 \sin\frac{G}{M} t \tag{18}$$

So:

$$x = \int u_x dt = \int_0^t u_0 \cos\frac{G}{M} tdt = \frac{Mu_0}{G} \sin\frac{G}{M} t \tag{19}$$

$$y = \int u_y dt = \int_0^t u_0 \sin\frac{G}{M} tdt = \frac{Mu_0}{G} (1 - \cos\frac{G}{M} t) \tag{20}$$

In the motor process of the volleyball, if there is only the horizontal velocity vertical not with velocity, after integrating the last equation, we have got:

$$z = \frac{gt^2}{2} \tag{21}$$

From the above discussion we can know that the key point of the research is to get the relationship between the movement distance and the horizontal direction of the volleyball. We can ignore the velocity in the vertical direction when the volleyball is hit and just think about the relative situation in the horizontal direction. It will make the operation simpler. When the t is eliminated, we have got:

$$(\frac{G}{Mu_0} x)^2 + (1 - \frac{G}{Mu_0} y)^2 = 1 \tag{22}$$

$$y^2 - \frac{2Mu_0}{G} y + x^2 = 0 \tag{23}$$

This equation is the formula of the volleyball's movement.

2.2 The analysis of the movement situation in the horizontal direction

From the above formula we can get:

$$y = \frac{Mu_0}{G} - \sqrt{(\frac{Mu_0}{G})^2 - x^2} \tag{24}$$

Due to the experience we know $M = 0.27kg$, $G = 8\pi\rho\omega r^3 / 3 = 0.11686\omega N$, if we substitute the constant into the above two equation, we can get the relation between the vertical and horizontal direction:

$$y = 23.1\frac{u_0}{\omega} - \sqrt{(23.1\frac{u_0}{\omega})^2 - x^2} \tag{25}$$

This is the formula of the movement when the volleyball is in rotation. From this we can know, there is some relationship between the drift distance in the horizontal direction and the correlation index of the air friction. The larger the number is, the greater the effect of the air friction is so that the slower the velocity of the volleyball is. But it will increase the displacement in the horizontal direction. Besides it also have certain relationship with the air density.

3 The mechanical model in the process of the volleyball spiking

From the take-off of the volleyball player, if he keeps the time short enough he can get the max height, because of the inverse proportion between h and buffer time t_1. For the volleyball player, if more buffer time is spent in the take-off, more recovery time of muscle will be cost, which will influence the effect of the take-off.

In the process of pedal, the relationship between the height h and the pedal of take-off t_2 is also in inverse proportion, which shows the time spent in the take-off should not be so long. Besides, there is the time of volleyball's ball control t_3, the time of double- foot support t_4, the time of the right-foot pedal t and so on. Other relative parameters are shown in Table 1:

Table 1: The parameter table of the height of volleyball jump spike and time-consuming

	t_1	t_2	t_3	t_4	t
r	-0.70	-0.60	-0.40	-0.38	-0.75
p	< 0.02	< 0.05	> 0.04	< 0.04	< 0.05

In order to analyze the relationship between velocity and center of gravity, we study the height of center of gravity h and the parameter of the relative velocity. The relative parameter is shown in Table 2:

Table 2: The relevant coefficient tables of the vertical velocity parameter of body center of gravity and H

	Strike the ground on right foot	Minimum center of gravity	Both feet off the ground	The loss of horizontal velocity	The loss ratio of horizontal velocity
$x \pm s$	2.50 ± 0.80	1.70 ± 0.60	0.56 ± 0.29	2.00 ± 0.71	0.85 ± 0.05
r	$0.60(P < 0.02)$	$0.50(P > 0.03)$	$-0.77(P < 0.02)$	$0.83(P < 0.02)$	$0.85(P < 0.02)$

Table 2 shows the relationship between the volleyball player's center of gravity and velocity. From that we can know the volleyball player's center of gravity and the horizontal velocity when the player strike the ground on right foot is in a moderate relationship, which is negative correlated with the horizontal velocity when both feet off the ground, and is positive correlated with the loss ratio of horizontal velocity. So this shows if the larger the lower limbs' buffer speed is, the more the loss of horizontal velocity is, and the bigger the motivation of the player is. This is caused by the large approach speed which makes the player jump higher.

Table 3 shows the relevant coefficient tables between the height of player's center of gravity and the vertical velocity:

Table 3: The relevant coefficient tables of the vertical velocity parameter of body center of gravity

	Strike the ground on right foot	Minimum center of gravity	Both feet off the ground	The loss of horizontal velocity	The loss ratio of horizontal velocity
$x \pm s$	-0.60 ± 0.25	0.45 ± 0.20	2.98 ± 0.15	0.90 ± 0.18	1.25 ± 0.30
r	$-0.15(P > 0.03)$	$0.14(P > 0.03)$	$0.80(P < 0.01)$	$0.13(P > 0.03)$	$0.38(P > 0.03)$

From Table 3 we can see the height of player's center of gravity and the vertical velocity is not in a functional relation but a relationship of correlation. The material point of the player when he is moving includes thermal energy, chemical energy and so on, not just the mechanical energy. So they are not in a functional relation.

4 The analysis of the rotation problem in the volleyball's movement

We choose 20 volleyball players as the research target. There are 10 in the control group and 10 in the experimental group. The arrival rate will be in management when each group gets10 side spins balls. This is shown in Table 4:

Table 4: the Statistical tables of the control group and the experimental group

Number of times	1	2	3	4	5	6	7	8	9	10
The arrival number of the experimental group	8	9	9	10	7	8	10	9	6	7
The arrival number of the control group	7	6	4	5	8	7	4	5	4	8

After the calculation process, we get the following Table 5:

Table 5: computation sheet

group	The experimental group		The control group	
number	x_1	x_1^1	x_2	x_2^2
	8	78	7	30
	7	64	8	18
	6	51	5	52
	9	69	3	67
	9	80	4	10
	9	75	6	15
	10	84	7	18
	7	52	5	24
	8	56	6	17
	7	40	5	31
$\sum$	78	637	48	265

Assuming the overall standard deviation is the same when the player is in the process of receiving the volleyball, then we take $a = 0.05$ as inspection, considering that the total amount is small, therefore, this paper applied t distribution to validate, its formula is:

$$t = \frac{|\overline{x_1} - \overline{x_2}|}{ec\sqrt{\frac{1}{n1} + \frac{1}{n2}}} \tag{26}$$

In this function

$$ec = \sqrt{\frac{\sum x_1^2 - \frac{\sum (x_1)^2}{n1} + \sum x_2^2 - \frac{\sum (x_2)^2}{n2}}{n1 + n2 - 2}} = \sqrt{\frac{654 - \frac{6400}{10} + 272 - \frac{2500}{10}}{10 + 10 - 2}} = \sqrt{\frac{14 + 22}{18}} = \sqrt{2} \approx 1.414$$

Because:

$$\overline{x_1} = 8, \ \overline{x_2} = 5$$

$$t = \frac{|\overline{x_1} - \overline{x_2}|}{ec\sqrt{\frac{1}{n1} + \frac{1}{n2}}} = \frac{|8 - 5|}{1.414 \times \sqrt{\frac{1}{10} + \frac{1}{10}}} \approx 3.15$$

Through the theory of probability and mathematical statistics in the t distribution of the probability of the table, we can know that: when $dt = 18$, then

$$t_{0.05}(18) = 2.102$$

$$t = 3.15 > t_{0.05}(18) = 2.102$$

So that we can get the result of test t, that is: $P < 0.05$, through the above data we know that the obvious differences between the control group and experimental group.

5. The analysis of the loiters phenomenon in the process of volleyball games

In the process of volleyball sport, the feet will separated from the ground after the athletes jumping, which will be effected by the gravity and the resistance of the air, but because the air resistance is fairly small, so it will not be considered. According to the oblique projectile motion principle, the height will be determined by the speed of the vertical direction in the process of players jumping and the velocity in horizontal direction is determined by the initial state.

This article chooses six athletes to analyzes, first these players mastered the action of three standards through training, and all of parameters of the six athletes are shown in Table 6 below:

Table 6: the basic situation of the object

Age	height(m)	weight(kg)	High of the approachable touching (m)	Main project of Sport years
23.1 ± 2.5	1.90 ± 0.05	77.4 ± 4.51	3.24 ± 0.20	8.5 ± 2.86

One of the three standard of the action is jumping with arm swinging, then straight the legs, the other is maximum vertical jump, after which they smash, thirdly, the players swing arms continuously in the process of jumping. Three types of actions are to be carried out under the condition of no. 4 position of run-up training. Then we analyze the speed performances of the six athletes and get the following table 7:

Table7. The analysis of variance of three types of jumping action of gravity vertical speed

Source	sum of squares	variance	Variation of the mean square	F numbers	P
inter-group	1.56	4	0.68	35.00	< 0.02
Intra-group	0.31	11	0.03		
total	1.87	15			

Through the above-table 7 is not hard to find, due to the different styles of the athletes' takeoff, so there are significant differences between the three actions in the vertical direction. In addition, we can have more experience by comparing the average, which are shown in table 8 below:

Table 8: the comparison of the average vertical velocity of three jump action

antithesis	Q numbers	span	P
group1:group 3	3.61	3	> 0.04
group 1:group 2	12.12	4	< 0.02
group 3:group 2	8.41	3	< 0.02

By the above-mentioned table 8, It can be seen that there is no significant difference between the first and second movement, and the third movement is of great different comparing with the other two terms, this is because the hand waving obviously is able to increase the accelerated velocity in the process of upward leaping when the athlete jump upward, so it makes the whole body velocity increases instantaneously. The analysis of the horizontal speed for the above three kinds of actions are the following Table 9:

Table 9: the analysis of variance of three types of jumping action of horizontal speed

Source	sum of squares	variance	Variation of the mean square	F numbers	P
inter-group	0.32	3	0.15	1.34	> 0.03
Intra-group	2.14	12	0.12		
total	2.46	15			

Through the above-mentioned 9 is not hard to find that there is no significant difference between the three movements in horizontal direction, so that three different kinds of actions have no effect on horizontal speed.

In order to distinguish the circumstances of the influence of the speed of the horizontal and vertical direction when they are in duration, in this paper, the analysis and research of that is divided into two groups, we can get table 10 after dealing with the data.

Table 10:The average comparison of horizontal and vertical velocity of Duration

Speed	In Duration	Out Duration	T number	P
horizontal	180.26 ± 36.14	170.58 ± 27.56	0.35	> 0.04
vertical	360.17 ± 20.36	360.21 ± 15.04	0.31	> 0.04

It is can be seen from the table 10 that either in vertical direction and horizontal direction of the speed has few effects on the duration.

CONCLUSION

(1) we can prove that teaching is one of the effective ways to improve the volleyball pass rate combined with theory and practice by applying the contrast experiment, which need specific training and the analysis of the theory, Only through the combination of theory and practice can make process of servicing and receiving of the rotation volleyball achieve its greatest potential.

(2) in terms of the knee Angle changes of players in duration, because $p < 0.05$ hence its center of gravity to jump and the time height has few relationships, it does not mean that the higher they jump, the better the duration degrees is, but rather to see the contraction of joints and the cooperation with the arms, etc. Therefore we obtained that the technology of the duration is mainly influenced by the flexibility, strength, cooperation.

In the light of exhaust the kinematics analysis, we put forward that the lateral drift distance of the volleyball is related to the correlation coefficient of air resistance, the greater its value, the bigger the role of the resistance of the air, so that it makes the volleyball movement become slower, but it will increase the displacement of the horizontal movement, in addition there is also a connection with the density of air.

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