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Research on the Application of ADAMS Dynamics in the Teaching of Throwing and Catching in Rhythmic Gymnastics

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Abstract:

In the teaching of ball exercise in rhythmic gymnastics, throwing and catching is one of the important teaching contents of ball exercise. In order to improve the teaching quality of this skill, it is necessary to combine theory with practice to study it. In this paper, ADAMS dynamics is applied to the teaching of throwing and catching in rhythmic gymnastics course in colleges and universities. The research results can not only promote the integration of fluid mechanics principle, and difficult beauty items, but also provide valuable theoretical basis for the first-line teaching of throwing and catching in ball gymnastics. The innovative research results are as follows: The velocity, displacement and trajectory curve data of the ball thrown from five angles in Rhythmic Gymnastics are obtained, and the correlation between the Angle parameters of the ball thrown and the falling time, velocity and displacement of the ball in Rhythmic Gymnastics is confirmed. And give advice: professional teachers should be under the perspective of "advancing with The Times", complete sets of movements for ball from different angles and levels of theory and practice of teaching research and exploration, to other areas of study principle and course practice teaching combination, multidimensional, deep implementation of the teaching reform practice, to explore the suitable to the new mode of teaching development.

Keywords*: Rhythmic gymnastics, ball exercise, throwing and catching the ball.*

I. INTRODUCTION

In recent years, with the construction of sports performance major in Colleges and universities in the new era tends to be systematic and integrated, rhythmic gymnastics has become the core course in the talent training program with the advantage of being in the forefront of difficult and beautiful projects. In order to improve the teaching quality of the course, front-line teachers need to dialectically analyze the four core elements of rhythmic gymnastics, namely, stability, accuracy and dexterity. In the teaching of rhythmic gymnastics, throwing and catching the ball is one of the important teaching contents. In order to improve the teaching quality of the technical movements, it is necessary to study the combination of theory and practice. Fluid mechanics is one of the research methods of aerodynamics of sphere in sports engineering. In this paper, Adams dynamic analysis software is used to simulate and analyze the throwing and catching action of rhythmic gymnastics, and the velocity, displacement and trajectory curve data of different angles are obtained. In this paper, its theory and ADAMS dynamics are mixed and applied to the course teaching of rhythmic gymnastics. The research results can not only promote the integration of fluid

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mechanics principle, digital voice technology and difficult aesthetics project research, but also provide valuable theoretical basis for the first-line teaching of ball gymnastics throwing and catching technique.

II.THE ESTABLISHMENT OF GYMNASTIC MODEL IN ADAMS

2.1 Introducing sphere model into rhythmic gymnastics

In this study, the pictures of rhythmic gymnastics equipment were saved in step format and imported into Adams dynamic analysis software, and the corresponding material density was given.

2.2 Three dimensional solid modeling of rhythmic gymnastics sphere

The three-dimensional simulation model of rhythmic gymnastics ball apparatus studied in this paper is shown in the figure below.

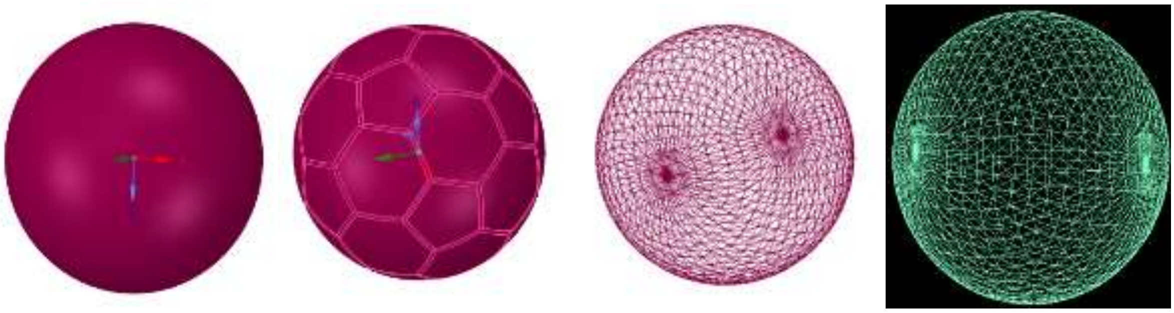

Fig 1:3D simulation model

2.3 Defining component properties

TABLE 1.Parameter setting of rhythmic gymnastics ball

PROJECT	PARAMETER
DENSITY/(kg·m-3)	1210
ELASTIC MODULUS/GPA	0.0078
POISSON'S RATIO	0.47

The first step of this study: set the quality information of all parts, select geometry shape and material type as the way to define quality, and select steel as the material type. The density, elastic modulus and Poisson's ratio are set by changing the values of density and other parameters by right clicking the material type and selecting parameterization. The second step: verify the model after the parameter setting to prevent missing the attribute setting of a part. The parameters of rhythmic gymnastics ball studied in this paper are shown in Table 1.

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2.4 Determining constraints between components

When the models are imported into the Adams TM software, there is only a relative position relationship between them. In order to prevent the components from separating from each other in the simulation process, it is necessary to constrain the devices to determine the relationship between them. When constraints are established between components, marker points are automatically generated to determine the position of constraints. Marker points are produced with the emergence of constraint relations. In the actual situation, users can also manually add marker points to mark the position of concern, and get the force, displacement and other information in the simulation results. Therefore, this study created a good marker point, released all the degrees of freedom of the ball instrument in the research process, only controlled its initial movement direction.[1]

2.5 Setting the number of simulation steps

In order to improve the simulation accuracy, the simulation time is 5S and the number of simulation steps is 2000.

III.THE ORETICAL BASIS OF MULTI-BODY OF MULTI-BODY DYNAMICS FOR BALL INSTRUMENTS

Multi-body dynamics refers to the science of studying the motion law of a complex multi-body system which is connected by several rigid bodies or flexible bodies through certain constraint relations. According to whether there are flexible bodies in the model of multi-body dynamics, it can be divided into multi-body dynamics and multi-body dynamics; according to the constraint relationship, it can be divided into ideal holonomic constraint, nonholonomic constraint, steady constraint and unsteady constraint.

3.1 Principle of multi-body dynamics algorithm for ball instruments

For complex multi rigid body systems $B_i = (1, \cdots, n)$, on behalf of the rigid body, the earth is defined as zero rigid B_0, according to the actual situation to choose the appropriate inertial reference base $e^{(0)}$, science to determine the applicable to the rigid body attached base $e^i (i = 1, \cdots, n)$, the origin O_i and centroid C_i coincide exactly. In practice, in order to accurately and efficiently define the current region of all rigid bodies Bi, it is necessary to select three basic components of the position vector r_i of centroid C_i of the rigid body $(x, y, z)_i$, so as to realize the accurate and definite position. At the same time, according to the three Euler angles $(\psi, \theta, \phi)_i$ of the connected basis e^i, the direction can be determined reasonably and conveniently, so that the positions of all rigid bodies can be determined accurately and efficiently[2]. In view of this, this paper considers that the position vector can be expressed accurately and clearly by 6×1 matrix:

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$$x_i = [x, y, z, \varphi, \theta, \phi]_i^T \ (i = 1, 2, \cdots n) \tag{1}$$

In this way, the coordinates of each rigid body can be expressed, which is called Cartesian generalized coordinates. If we observe this coordinate formula carefully, we can know that no matter which rigid body it is, it has six corresponding Cartesian coordinates and it contains a multi-rigid body system of *n* rigid bodies. Its coordinate number is defined as 6*n*.The expression is as follows:

$$x(t) = [x_1^T, x_2^T, \cdots x_n^T]^T = [x_1, x_2, \cdots x_{6n}]^T \tag{2}$$

In the process of multi rigid body dynamic system calculation, it can be accurately and reasonably expressed by 3×1 position matrix r_i of centroid Ci and cosine matrix A_i in 3×3 direction which can clearly and intuitively describe the transformation relation $e^0 = A_i e^{(i)}$. The Cartesian coordinates of r_i and A_i are as follows:

$$r_i = r_i(x) A_i = A_i(x) (i = 1, \cdots, n) \tag{3}$$

The velocity and acceleration matrices of the centroid of the rigid body can be obtained by calculating the first and second derivatives of the position matrix r_i respectively:

$$(4) v_i = \dot{r}_i = \sum_j^{6n} \frac{\partial r_i}{\partial x_j} \dot{x}_j = \frac{\partial r_i}{\partial x} \dot{x} = H_{T_i}(x) \dot{x}(x)$$

$$(5) a_i = \ddot{r}_i = \sum_{j=1}^{\sigma n} \frac{\partial r_i}{\partial x_j} \ddot{x}_j + \sum_{k=1}^{\sigma n} \sum_{j=1}^{\sigma n} \frac{\partial^2 r_i}{\partial x_j \partial x_k} x_j \dot{x}_k$$

$$= \sum_{j=1}^{\sigma n} \frac{\partial r_i}{\partial x_j} \ddot{x}_j + \sum_{k=1}^{\sigma n} \frac{\partial v_i}{\partial x_k} \ddot{x}_k = \frac{\partial r_j}{\partial x} \ddot{x} + \frac{\partial v_i}{\partial x} \dot{x}$$

$$= H_{T_i}(x) \ddot{x}(t) + \frac{\partial v_i}{\partial x} \dot{x}(t)$$

From the above two formulas, the matrix can be obtained:

$$(6) H_{T_i}(x) = \frac{\partial r_j}{\partial x} = \frac{\partial v_j}{\partial \dot{x}}$$

In general, the direction cosine matrix is used to represent the angular velocity matrix of rigid body B_i in the inertial basis e^0:

$$(7) w_i = \begin{bmatrix} 0 & -w_{i3} & w_{i2} \\ w_{i3} & 0 & -w_{i1} \\ -w_{i2} & w_{i1} & 0 \end{bmatrix} = A_i A_i^T$$

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If the directional cosine matrix A_i has been defined, then the component w_i of angular velocity vector can be directly derived from this condition. Combined with kinematic theory, w_i can be further described as follows: $w_i = H_{R_i}(x)\dot{x}(t)$.The acceleration matrix can be obtained by simultaneously deriving both sides of the above formula:

$$(8)\dot{x_i} = H_{R_i}(x)\ddot{x}(t) + \frac{\partial w}{\partial x}\dot{x}(t)$$

$H_{R_i}$is the coefficient matrix, which can be obtained in generalized coordinates by the following formula: $H_{R_i} = \frac{\partial w_i}{\partial \dot{x}}$Through the derivation of the above formula, the velocity of the centroid, the acceleration of the centroid, the angular velocity of the centroid and the angular acceleration of the centroid of any rigid body in the Cartesian generalized coordinate system can be obtained.

3.2 Dynamic analysis of holonomic constrained system

Suppose *n* rigid bodies constitute a multi rigid body system, and there are *m* unsteady holonomic constraints between rigid bodies under the action of connecting hinges. The constraint equation can be expressed as follows:$\varphi_s(x,t) = 0(s = 1, \dots, n)$.The degree of freedom of multi rigid body system is K=6*n*-m, and 6*n* Cartesian generalized coordinates are not independent. To describe the whole configuration of the system, *N* independent generalized coordinates$q_j(j = 1, \dots, N)$, should be selected and expressed as N×1 position matrix in the form of matrix:$q(t) = [q_1, q_2, \dots, q(n)]^T$.Based on the above formula, we can clearly and intuitively realize that no matter what kind of Cartesian generalized coordinates are, in essence, the functions of coordinates q and time t : $x = x(q, \mathrm{t})$, the vector radius matrix and direction cosine matrix of the centroid position of each rigid body B_i can be expressed by the generalized coordinates q and time t :

$$(9) r_i = r_i(q,t), A_i = A_i(q,t) \quad (i = 1, \dots, n)$$

It can be seen that the relationship between Cartesian generalized velocity $\dot{x}$ and independent generalized velocity $\dot{q}$ is linear:

$$(10)\dot{x} = \frac{\partial x}{\partial q}\dot{q} + \frac{\partial x}{\partial t} = F\dot{q} + \frac{\partial x}{\partial t}$$

F is the coefficient matrix and $F = \frac{\partial x}{\partial q} = \frac{\partial \dot{x}}{\partial \dot{q}}$ is substituted, the velocity and angular velocity of the rigid body centroid can be expressed in the holonomic constrained system:

$$(11) \mathrm{v}_i = J_{T_i}(q,t)\dot{q}(t) + v_{it}$$

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$$(12) w_i = J_{R_i}(q,t)\dot{q}(t) + w_{it}$$

It can be obtained after conversion:

$$(13) J_{T_i}(q,t) = \frac{\partial v_i}{\partial \dot{q}} = H_{T_i}F$$
$$(14) J_{R_i}(q,t) = \frac{\partial w_i}{\partial \dot{q}} = H_{R_i}F$$

It is called the geometric Jacobian matrix and represents the function of the generalized coordinates relative to time.They can be obtained by right multiplying matrix H_{T_i} and H_{R_i} by matrix F.$v_{it} = \frac{\partial r_i}{\partial t}$ and w_{it} are the partial derivatives of v_i and w_i respectively. Therefore, for a steady system, v_{it} and w_{it} are both zero.The above two formulas are used to derive the time t respectively, so as to obtain the acceleration and angular acceleration matrix of each rigid body centroid:

$$(15) a_i = J_{T_i}(q,t)\ddot{q}(t) + \frac{\partial v_i}{\partial q}\dot{q}(t) + \frac{\partial v_i}{\partial t}$$
$$(16) w_i = J_{R_i}(q,t)\ddot{q}(t) + \frac{\partial w_i}{\partial q}\dot{q}(t) + \frac{\partial w_i}{\partial t}$$

3.3 Dynamic analysis of angle of nonholonomic constrained system

Suppose that in a system with n rigid bodies, there are not only m_1 holonomic constraints, but also m_2 nonholonomic constraints. The configuration of the system can be represented by 6n Cartesian generalized x coordinates, as shown in the formula. The existence of two different types of constraints directly means that neither Cartesian generalized coordinates nor generalized velocity have strong independence. Therefore, we should choose $N = 6n - m_1$ generalized coordinate q which can keep high independence. The number of degrees of freedom is $k = 6n - m_1 - m_2 = 6n - m$.$m_1$ holonomic constraints can be expressed as follows:$\emptyset(x,t) = 0$ (s=1,…,m_1).m_2 nonholonomic constraints can be expressed as follows:$\Psi(q,\dot{q},t) = 0$ (s=1,…,m_2).K independent generalized velocities are selected and expressed in matrix form as follows:$u(t) = [u_1, u_2, \ldots, u_k]^T$Then the independent generalized coordinate q , the generalized velocity u and the time t can be used to express the independent generalized coordinate $\dot{q}$:$\dot{q} = \dot{q}(q,u,t)$According to the above formula, the velocity and angular velocity matrix of rigid body can be expressed in nonholonomic constraint system as follows: $v_i = v_i(q,u,t)$, $w_i = w_i(q,u,t)$ .The expressions of the acceleration matrix and angular acceleration matrix of the centroid of a rigid body can be derived by derivation:

$$(17) a_i = L_{T_i}(q,u,t)\dot{u}(t) + \frac{\partial v_i}{\partial q}\dot{q}(t) + \frac{\partial v_i}{\partial t}$$
$$(18) w_i = L_{T_i}(q,u,t)\dot{u}(t) + \frac{\partial w_i}{\partial q}\dot{q}(t) + \frac{\partial w_i}{\partial t}$$

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After transforming the above two formulas, the matrix is obtained:

$$(19) L_{T_i}(q,u,t) = \frac{\partial v_i}{\partial u} = \frac{\partial v_i}{\partial \dot{q}}\frac{\partial \dot{q}}{\partial u} = J_{T_i}G = H_{T_i}FG$$

$$(20) L_{T_i}(q,u,t) = \frac{\partial w_i}{\partial u} = \frac{\partial w_i}{\partial \dot{q}} = J_{R_i}G$$

It can be seen from the formula that these two matrices are generalized coordinates, independent functions of velocity and time, namely kinematic Jacobian matrix, which can be directly determined by the multiplication of matrix H_{T_i} and H_{R_i} with $6n \times N$ matrix F and $N \times K$ matrix G, where $G = \frac{\partial \dot{q}}{\partial u}$, in a steady system, there is a partial derivative term for the derivative of time t, and both of them are zero.

IV. THE APPLICATION OF ADAMS DYNAMICS IN THE TEACHING OF THROWING AND CATCHING IN RHYTHMIC GYMNASTICS

The ball exercise teaching of rhythmic gymnastics is not only a simple body movement exercise, but also a complex teaching process in which the practitioners hold the rhythmic gymnastics ball and practice under the accompaniment of music. This paper summarizes the teaching contents of rhythmic gymnastics throwing and catching in some normal universities and independent institutes of physical education, and divides them into two categories: in-situ throwing and catching and moving throwing and catching, as shown in Table 2 and table3.

TABLE 2. Technical characteristics of "throwing and catching in situ" in different stages [3]

CLASSIFICATION	BEGINNING STAGE	MIDDLE STAGE	END STAGE
One handed up and two handed catch	One handed up throw	Stand on your toes where you are	two-hand catching
Throw the ball back with one hand and catch the ball in front of the other hand	Throw the ball back with one hand	Point the ground sideways from where you are	Catch the ball in front of your body with your other hand
Throw the ball forward with both hands and catch the ball in front of both hands	Throw the ball back with both hands	Stand on your toes where you are	Catch the ball in front of your body with both hands
Throw the ball forward with one hand and catch the ball with both hands behind			

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Lie on your stomach with both feet on the ball and throw the ball forward	Throw the ball forward with one hand	Stand on your toes where you are	Catch the ball behind your body with both hands
Lie on your stomach with both feet on the ball and throw the ball forward	Throw the ball forward with both feet	Lie prone in an inverted arch	Put your hands up to catch the ball

Table 3.Technical characteristics of "throwing and catching in motion" in different Stages [3]

Name	Beginning stage	Middle stage	End stage
One Handed Throw …Long jump catch	One Handed Throw	No other body movements	Long jump catch with one hand
Long jump throw …Long jump catch	Long jump throw with one hand	No other body movements	Long jump catch with one hand
One Handed Throw up…Sigle-leg stand back bend[4]	One Handed Throw	No other body movements	Sigle-leg stand back bend

4.1Teaching of throwing ball

Throwing the ball action refers to the artistic gymnastics ball equipment from the start of throwing to the ball release stage, before throwing the ball, there should be a different swing action, as the buffer force before throwing the ball, so that the ball can be carried out along the arc, and all throwing movements use the whole body strength [5]. The speed curve of the same quality rhythmic gymnastics ball when thrown at 80, 60, 45 and 30 degrees is shown in Fig. 2.

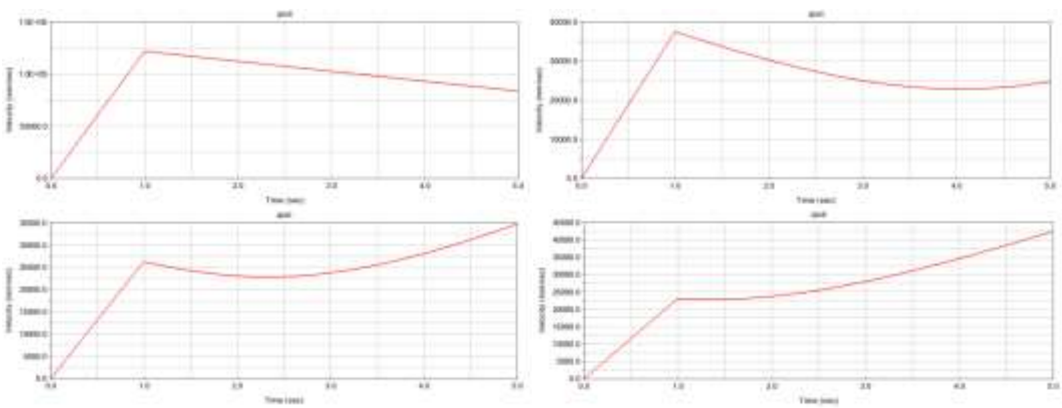

Fig 2: velocity curve of rhythmic gymnastics ball from different angles

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Fig.3 shows the speed contrast diagram of the same quality rhythmic gymnastics ball throwing in 80 degree direction, 60 degree direction, 45 degree direction and 30 degree direction respectively. As can be seen from the figure, when the ball instrument is thrown in the direction of 80 degrees, its speed is the maximum, and when the ball instrument is thrown in the direction of 30 degrees, its speed is the minimum. The results show that the velocity curve and size of the ball instrument in the air after being thrown out have a great relationship with the throwing direction; the ball instrument with the largest angle (< 90 degrees) has the largest flying speed in the air, otherwise, the smaller the speed.

TABLE 4.Teaching contents of "throwing and catching"

TEACHING OF THROWING	TEACHING OF CATCHING
Throw the ball low, in the middle with both hands in place	Catch the ball with both hands
Throw the ball low, in the middle with one hand in place	Catch the ball with one hand
Throw the ball low, in the middle with one hand in place	Catch the ball on the back of the hand
Throw the ball with one hand and both hands at different heights	Fancy catching
Low, medium and high throwing in motion	Fancy catching

In the practice of throwing the ball high, medium and low, combined with the teaching decomposition steps listed in Table 4, the teacher should let the students practice the two handed low throwing and medium throwing first, and then practice the single handed low throwing and middle throwing. Second, practice throwing the ball with one hand and two hands at different heights. Finally, practice throwing the ball low, medium and high in motion. As the core special skill of ball exercise, throwing and catching is not only a way of physical activity, but also a kind of mental activity. In order to improve the accuracy of the final catch, it is necessary for the practitioner to grasp the timing and direction of the ball. Only continuous hard practice, this knowledge can be transformed into skills and displayed on students.[6]

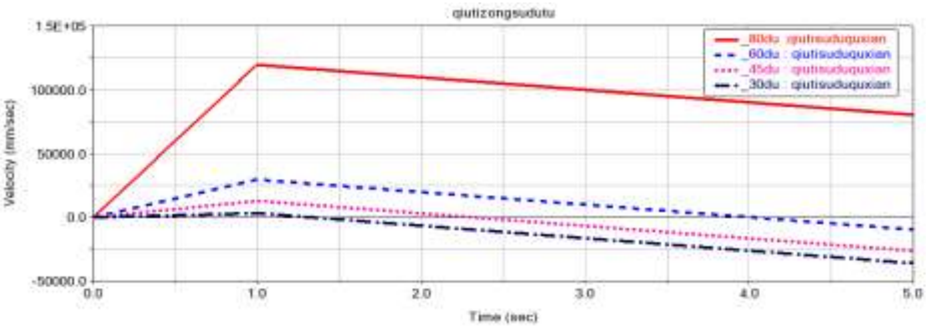

Fig 3: speed comparison of rhythmic gymnastics ball from different angles

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4.2Teaching of motion in air sports of ball equipment

Figure 4 shows the displacement curve of the same mass of rhythmic gymnastics ball when it is thrown at 80 degrees, 60 degrees, 45 degrees and 30 degrees. In the process of ball equipment moving in the air, the player needs to complete all kinds of body movements on the ground or in the air at the same time, such as: after fast rotation and large jump, then dump, roll, slide and flip in various positions; the practitioner and the ball should always be in the state of movement, and the ball holding and non holding movements should be closely coordinated in order to show the ball movement Dynamic [7]. The quality of these body movements depends on the length of the ball instrument's moving route in the air.In the teaching process, teachers should take oral teaching as a heuristic teaching method. In the initial stage of technical action learning, that is, when students imitate teachers or imitate others, the visual image formed is mainly spatial visual image. When the correct visual image is transformed into personal actual action, it depends on the combination of visual image and kinesthetic image, that is, the visual image becomes visual control, and the kinesthetic image is also transformed into kinesthetic control. The transition time varies from person to person and can only be obtained through repeated practice. Finally, the transformation from visual control to kinesthetic control is realized, so that students can master the action by visual control at the beginning, and then master the action by kinesthetic control. Under the control of consciousness, we can compare vision and movement, and enter the stage of using technical movements freely.

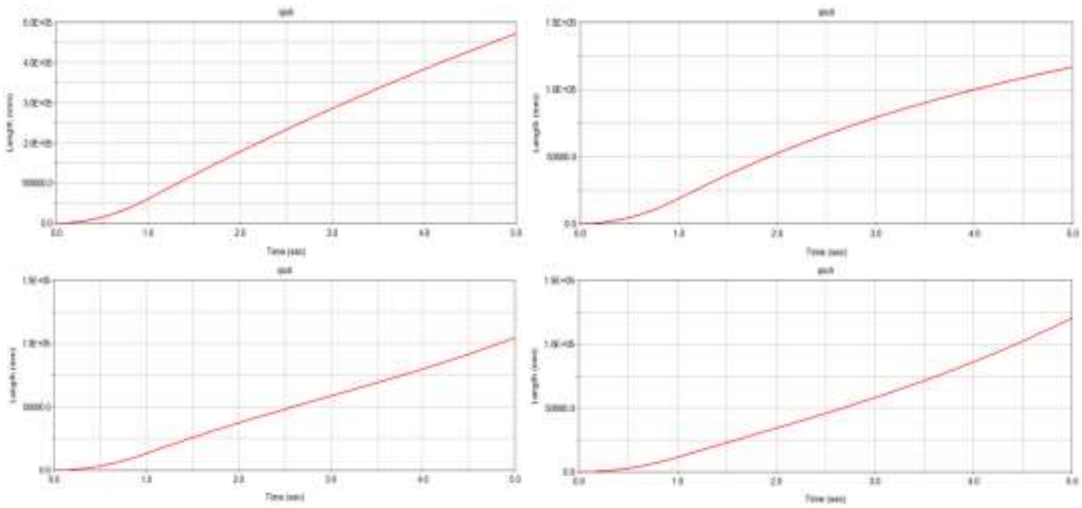

Fig 4: displacement curve of rhythmic gymnastics ball under different angles

Combined with the displacement curves in different directions shown in Fig.5, when the artistic gymnastics ball is thrown in the direction of 80 degrees, its displacement is the largest, while when it is thrown in the direction of 30 degrees, its displacement is the smallest and the rising height in the vertical direction is also the lowest. The larger the throwing angle is, the greater the movement displacement of the ball instrument is, and the higher the vertical height is, and vice versa. Therefore, in the process of teaching at this stage, we need to practice two major contents separately. The first is to strengthen the practice of

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various body movements; the second is to freely control the length of time of artistic gymnastics ball in the air. On the basis of skilled operation of the above movements, the perfect integration of ball equipment and human body movements is the highest standard of teaching, and the combination of the two carries out integrity exercises, such as large span High quality body movements such as jump and catch, body forward bending and split leg rotation 360 combined with the ball.

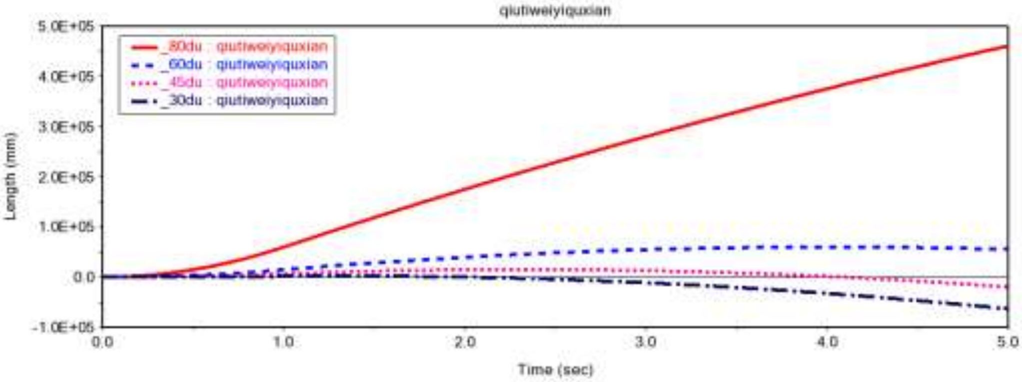

Fig 5: displacement comparison of rhythmic gymnastics ball under different angles

4.3Teaching of catching the ball

Figure 6 shows: the trajectory curve of the same quality rhythmic gymnastics ball throwing in the direction of 90 degrees, 80 degrees, 60 degrees, 45 degrees and 30 degrees. When the ball equipment is thrown in the direction of 80 degrees, the trajectory is the largest, and when the ball equipment is thrown in the direction of 90 degrees, the trajectory is the smallest. The results show that in the range of < 90 degrees, the trajectory curve of the ball instrument in the air after being thrown out has a great relationship with its throwing direction (non-90 degrees). The larger the throwing angle of the ball instrument is, the larger the trajectory is after flying out, otherwise, the smaller the trajectory is.

In the teaching process of catching the ball, the teaching steps followed by the teacher should correspond to the five steps in Table 4. Combined with FIG. 6, the trajectory curve of rhythmic gymnastics ball thrown under different forces and directions should be considered, no matter which way to catch the ball, we must consider that the potential of falling ball with acceleration will produce buffer force. Therefore, it is necessary to design the ready position for receiving the ball to maximize the release of buffer force, that is, the falling point of the ball continues to swing back or left and right. Teachers need to calmly explain each difficult action essentials clearly, accurately, and highlight the key points, so as to strengthen students' understanding of the action essentials and action process, and then let students practice to make the technical movements more standardized and improve the students' ability to master sports technology.

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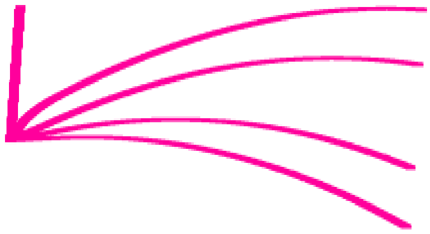

Fig 6: track curve of rhythmic gymnastics ball under different angles

V. CONCLUSIONS AND RECOMMENDATIONS

This paper simulates the same quality rhythmic gymnastics ball equipment throwing from 90 degrees, 80 degrees, 60 degrees, 45 degrees, 30 degrees, and obtains three big data of the ball velocity, displacement and trajectory curve, and analyzes the correlation between the throwing angle parameters and the time, speed and displacement of the artistic gymnastics ball falling. The simulation and analysis results are as follows:(1) The maximum angle (< 90 degrees) throw artistic gymnastics ball, flying out of the air speed is the largest, on the contrary, the speed is smaller, the ball throwing speed curve and size in the air has a great relationship with the throwing direction.(2) The larger the throwing angle is, the greater the movement displacement of the ball instrument is, and the higher the vertical height is, and vice versa.(3) In the range of < 90 degrees, the trajectory curve of rhythmic gymnastics ball in the air has a great relationship with its throwing direction (non-90 degrees).The bigger the throwing angle of ball equipment is, the larger the trajectory is after flying out, otherwise, the smaller the trajectory is.

As for the technical action of throwing and catching the ball, the strength and direction of throwing the ball affect the quality of stable catching. In the teaching process, teachers attach importance to the comparison and explanation of the labor-saving skills of throwing and catching the ball, which is one of the ways to improve the classroom teaching effect.[8]Ball gymnastics teaching of rhythmic gymnastics is a highly practical bilateral activity of physical education.It is suggested that professional teachers should conduct in-depth research and exploration on the theory and practice teaching of complete sets of movements of ball Gymnastics from different angles and levels from the perspective of "keeping pace with the times", integrate the research principles of other fields with the practice teaching of curriculum, and carry out the teaching reform practice in a multi-dimensional and deep-seated way. It is suitable for the new teaching mode of difficult and beautiful courses.

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