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Aerobics basic motions techniques' physical quality motor functions research based on human rigid multi-body dynamics model

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ABSTRACT

Aerobics is a well-received event with lots of body building efficiency. Long-term persist aerobics training can improve health, perfect physical quality, correct deformities , adjust psychological activities and help to cultivate a good temper. This paper takes body building as main research objects, establishes rigid multi-body human model and rigid multi-body sports model so as to provide theoretical basis for aerobics techniques details research by model. Apply experimental grouping method and mathematical statistics method in aerobics players' each body indicator analyzing to explore aerobics motor functions and provide mass base for aerobics popularization.

Key words: Aerobics, rigid multi-body dynamics model, Lagrange constraint factor, fitness efficiency

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INTRODUCTION

Aerobics is a newly developed sports event that combines music, dance, gymnastics and aesthetics into one, which is popular around the world with its own values and charms, and gain favors of the broad masses especially for the young students. This paper just with backgrounds of aerobics, explores aerobics basic motion techniques features, aerobics technical motions research methods and aerobics motor functions these three aspects so as to make contributions to our country public health and aerobics popularization.

For aerobics and rigid multi-body human model establishment, lots of people have made their efforts, by which propels to aerobics development and make contributions to public health ideas popularization. Among them, Lin Xue-Lian etc.(2009) makes analysis and comparison on FIG competitive aerobics competition law changes from 1997 to 2005, explores our country competitive aerobics techniques development directions, builds firm base for competitive aerobics earlier entering into big family of Olympic Games [1]; Han Guan Zhou(2006) makes observations and statistics on world aerobics championships top three players and our country players' whole set motions since 2002, analyzes motions' artistry and difficulty status, summarizes our country aerobics techniques shortcomings [2]; Yuan Qing-Ke etc.(2010) according to multi-body dynamics principle and human anatomy base, establish model on human upper limbs, deduce dynamical and kinematical equations, construct human upper limbs four rigid bodies four freedom degrees dynamical model, and verify model accuracy and validness [3-5].

In order to promote aerobics popularization among its amateurs and other masses, carry out analysis on fitness efficiency that aerobics generates so as to explore aerobics techniques analysis methods and aerobics motor functions features through attractions generated to players by experimental group and control group data differences and make contributions to more widely development of public health.

AEROBICS CLASSIFICATION AND FEATURES

Aerobics is product of era, is the reflection of basic gymnastics artistic, motorization, fitness tendency, which has good effects on practical fitness aspect; it comes from English words that is aerobic exercise, its classifications are body building aerobics, competitive aerobics and performance aerobics. This paper takes body building aerobics as

research objects, the event can be further subdivided according to human structure, age structure, training form and training targets [4].

Human structure classification: Head and neck aerobics, shoulder aerobics, chest aerobics, medulla aerobics, leg aerobics hip aerobics and finger aerobics.

Age result classification: the middle and old aerobics, youth aerobics, children aerobics and infant aerobics.

Training form classification: bare-handed aerobics, hand apparatus aerobics and specialized apparatus aerobics.

Training targets classification: warm-up aerobics, posture aerobics, weight loss aerobics rhythmic aerobics, body shape aerobics as well as running and jumping aerobics.

Aerobics features as high attitudes artistry ,intense rhythmic pattern and widely adaptation which can function as strengthen physical quality ,improve health, perfect body shape, cultivate dignified posture, adjust psychological activities and help to get a good temper, improve nervous system functions, develop physical quality ,increase aesthetic appreciation and enrich amateur cultural life. Make classification of its basic technical motions body structure as upper limbs motions and lower limbs motions. The above basic technical motions and training are as Table 1 shows.

Table 1: Upper limbs technical motions and lower limbs motions classification

Upper limbs motion classification	lower limbs motion classification	lower limbs motion name
Hand shape	March type	march, walk, word step, V step, stroll and run
Hip motion	Step forward type	Chasse and cross-chasse
Shoulder motions	ground type	toe ground and heel ground
Trunk motions	Leg raising type	Knee lift, swing leg, kick leg, skip and step curl
	Two legs type	close leg jump, split jump, jump jack, half squat and lunge

From Table 1 contents, it can know that aerobics main motions are basically concentrated on legs, but upper limbs motion cooperation is needed to strengthen movements' coordination. In upper limbs motions, arms motions basic status is as Table 2 shows.

Table 2: Arms basic motion features

Arms motions classification	Motion features defining	Motions change status
raise ,swing ,lift ,pull	Take shoulder as axis ,stretch arms straightly and raise towards one direction then stop in one position, its activity range can not go beyond 180 degree	Single arm or double arms forward ,backward side raising ,from which double arms can make same motions and different motions, can do it successively or cross
flexion and bending	It is up to elbow joint generate a certain bend angle	Elbow flexion and bending including chest forward flexion, shoulder side flexion, shoulder onward lateral flexion, shoulder downward lateral flexion, shoulder onward forward flexion, flexion between waist, head backward flexion, can make single arm motions ad also use double arms make simultaneous motion and make same actions successively
circle	Take shoulder joint as axis, arms movements during 180 ° -360 ° are called rolling, if movements go beyond 360 ° , then it calls circle	single arm or double arms forward roll, backward roll, internal roll and external roll, and can also classify into small roll, middle roll and big roll; two arms can make simultaneous movements and make movements successively

From above stated contents, analyze aerobics values, classification and technical motions features. To better research on aerobics basic motions and analyze trainers' human each joint mechanical features and space features in sports status, it can make a more refined plan on the event research. Therefore, this paper at first establish human rigid model that composed of main joints, then analyze rigid body translation dynamical model and rigid body rotation dynamical model, so that apply human main joints composed rigid model and dynamical model to provide model base and theoretical basis for aerobics players motion statuses' motion analysis and diagnosing.

HUMAN RIGID MODEL ESTABLISHMENT AND MOTIONS ANALYSIS

Human rigid multi-body model

Human possess classified two typical dynamical features as limited particles system and adjacent joints interactions, to satisfy the two typical dynamical features, it establishes human rigid multi-body model in paper. The model divides human into 16 joints, each joint distribution status is as Figure 1 shows.

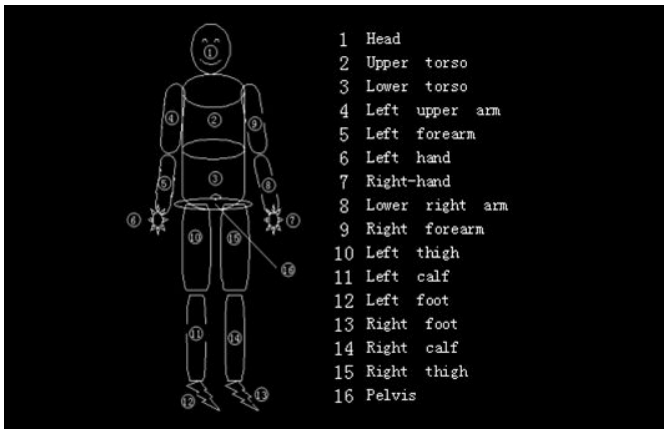

Figure 1：Human rigid multi-body model each joint schematic figure

If human each joint center relative position does not change during movement process, it can proportionally determine each joint center relative position according to definite proportion points' section division, its sections division proportion λ computational method as formula (1) shows.

$$\frac{x_i - x_{ij}}{x_i - x_j} = \frac{y_i - y_{ij}}{y_i - y_j} = \lambda \tag{1}$$

In formula (1), λ represents human each joint center position ratio，$(x_i, y_i), (x_j, y_j)$ respectively represents human one joint initial point and ending area coordinate，(x_{ij}, y_{ij}) represents human such joint center coordinate.

Concentration reflecting point that Human gravity bears is gravity center, its coordinate position is related to human posture that aerobics players each sport status will generate gravity center position. After human each joint status defined, its gravity center coordinate will also be defined, therefore human gravity center coordinate computational method as Formula (2) sows.

$$\begin{cases} X_C = \dfrac{\sum_{i=1}^{16} (mg)_{xi} \times x_{ij}}{\sum_{i=1}^{16} (mg)_{xi}}, Y_C = \dfrac{\sum_{i=1}^{16} (mg)_{y_i} \times y_{ij}}{\sum_{i=1}^{16} (mg)_{y_i}} \\ n = \dfrac{(mg)_{xi} \times x_{ij}}{\sum_{i=1}^{16} (mg)_{xi}} = \dfrac{(mg)_{y_i} \times y_{ij}}{\sum_{i=1}^{16} (mg)_{y_i}} \end{cases} \tag{2}$$

In formula(2), (X_C, Y_C) represents aerobics player body gravity center coordinate，$(x_{ij}, y_{ij})(i, j = 1,2,3,\cdots,16)$ represents each joint center coordinate，n is one joint relative quality in coordinate direction.

To carry out simple and reasonable calculation of young women and men aerobics players, gets Table 3 showing human each joint center definite proportion point ratio and relative quality percentage by applying regress analysis method.

Table 3: Chinese youth human body each joint center definite proportion point and relative quality percentage

Young male			Young women		
Ratio	Coordinate	Mass	Ratio	Coordinate	Mass
Hand	50.000%	0.642%	Hand	50.000%	0.493%
Forearm	41.869%	1.299%	Forearm	42.723%	1.182%
Upper arm	48.623%	2.609%	Upper arm	46.909%	2.622%
Foot	44.011%	1.498%	Foot	44.000%	1.383%
Calf	40.912%	4.010%	Calf	40.631%	4.549%
Thigh	47.709%	14.011%	Thigh	45.880%	14.278%
Upper torso	53.728%	16.992%	Upper torso	54.269%	16.531%
Lower torso	40.551%	25.603%	Lower torso	47.363%	25.875%
Trunk	44.001%	42.695%	Trunk	44.000%	42.703%
Head	50.000%	9.299%	Head	50.000%	8.604%

Apply data in Table 3 and formula (1) and formula (2) computational formula; it can get aerobics players' human gravity center position in one state.

Aerobics human rigid body dynamical base

Due to human possess classified two typical dynamical features as limited particles system and adjacent joints interactions, while limited particle from human composition is a quality abstract that ignore size and shape; in the fixed rigid joint, any two particles distance can be regarded as that it remains the same, as Figure 2 shows the rigid body three Cartesian coordinates $P=(x,y,z)^T$，and every posture has three Euler angles that is $\Lambda=(\varphi,\theta,\phi)^T$.

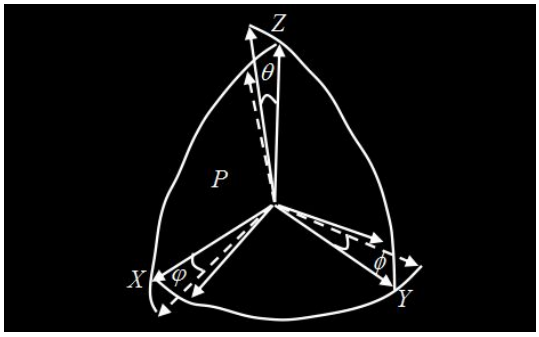

Figure 2：Rigid body model generalized coordinate system

As rigid generalized coordinate showing in Figure 2，use $q_i=[P_i \quad \Lambda_i]^T$ representing rigid body generalized coordinate，it has rigid body generalized speed v_i as formula(3) shows.

$$v_i=\frac{dq_i}{dt}=\dot{q}_i=\begin{Bmatrix}\dot{P}_i\\ \dot{\Lambda}_i\end{Bmatrix}=\begin{Bmatrix}v_t\\ \omega_i\end{Bmatrix} \tag{3}$$

If rigid quality is m， rigid body translation kinetic energy can as formulas (4) shows：

$$K_i=\frac{1}{2}(\dot{x},\dot{y},\dot{z})m(\dot{x},\dot{y},\dot{z})^T=\frac{1}{2}m\dot{r}^2 \tag{4}$$

In formula(4), r represents rigid body center radius vector，while $\dot{r}$ represents rigid body center's speed. Rigid body rotation kinetic energy can as formula(5) shows：

$$K_r=\frac{1}{2}(\omega_x,\omega_y,\omega_z)\begin{bmatrix}I_{xx}&0&0\\0&I_{yy}&0\\0&0&I_{zz}\end{bmatrix}\begin{bmatrix}\omega_x\\\omega_y\\\omega_z\end{bmatrix}=\frac{1}{2}\omega_i I\omega_i^T \tag{5}$$

Rigid body possessed total kinetic energy is (4)+(5)=$K=K_i+K_r$.

Human rigid multi-body system movements Lagrange model

Dalembert principle describes particle system all outside force and all particle inertia force are composed of a balance force system, as formula (6) shows.

$$F_i^e+F_i^i+(-m_i\dot{r}_i)=0 \tag{6}$$

In particle system that possesses ideal constraint, virtual displacement principle describes that particle system active force virtual work sum in any virtual displacement is zero, as formula (7) shows.

$$\sum_i \delta r_i\cdot(-m_i\dot{r}_i+F_i^e)=0 \tag{7}$$

For system that composed of n rigid bodies, it similarly meets Dalembert principle. If system has multiple rigid bodies, then every rigid body should meet formula (8) shows first kind Lagrange equation with Lagrange multipliers and corresponding constraint equation.

$$\begin{cases} \dfrac{d}{dt}\left[\dfrac{\partial K}{\partial \dot{q}_j}\right]-\dfrac{\partial K}{\partial q_j}+\sum_{i=1}^{n}\dfrac{\partial \Psi_i}{q_j}=F_j \\ \Psi_i(q_i,t)=0 \end{cases} \tag{8}$$

In formula(8), K shows total kinetic energy，q_i shows generalized coordinate，Ψ_i shows system constraint equation，F_j shows generalized coordinate directions' generalized force.

AEROBICS MOTOR FUNCTIONS RESEARCH

Research objects and methods

Research objects :Continuously participating mass fitness movements healthy women, from which experiment group members are 30 people from age 18 to age 40,20 people from age 41 to age 55, control group members are 27 people from age 18 to age 40,20 people from age 41 to age 55.

Research process: Apply adults human physical quality measurement handbook body shape features height, weight, function features resting rate, lung capacity, physical quality features grip, seated body forward flexion and vertical jump as indicator measurement values, make significant analysis of same age phase experimental group members and control group members.

Research method: mathematical statistics method, inductive analysis and document literature.

With expectation of using above research ways, makes reasonable estimations of aerobics players' effects that provides good mass base and data basis for aerobics popularization and development.

Aerobics efficiency analysis

Proportion of people that experiment group and control group cover the standard weight range status is as Table 4 shows.

Table 4： Experimental group and control group weight standard comparison

Weight type	Experimental group		Control group	
	Numbers of people	Proportion	Numbers of people	Proportion
Standard weight	34	68 %	22 people	46.81 %
underweight	13 people	26 %	14 people	29.79 %
overweight	3 people	6 %	11 people	23.40 %

From Table 4 data can know that experiment group aerobics training female is superior to control group ones in body shape.

Female from age 18 to 40 and from age 41 to 55 among experimental group and control group members' functional indicator lung capacity and heart rate comparison status is as Table 5 data shows.

Table 5：Experiment group and control group members body function comparison

Body function indicator	Members from age 18 to 40			Members from age 41 to 55		
	Experimental group	Control group	Significance	Experimental group	Control group	Significance
Lung capacity(ml)	2887.50 ± 465.15	2523.04 ± 289.16	$P<0.01$	2453.85 ± 372.96	2168.25 ± 290.09	$P<0.01$
Heart rate HR(time/min)	72.80 ± 3.26	76.00 ± 6.40	$P<0.05$	74.00 ± 4.79	77.80 ± 9.70	$P<0.01$

Data in Table 5 indicates that experimental group has an advantage over control group on body functions lung capacity average value at a same age stage, similarly experimental group's average heart rate value also superior to that in control group.

Experimental group and control group's age 18 to 40 female and age 41 and 55 female physical quality indicators as grip ,vertical jump, seated body forward flexion, single foot jump with eyes closed, sit-up and reaction time such 6 indicators data comparison status as Table 6 data shows.

Table 6：Experimental group and control group members' physical quality indicator data comparison

Physical quality indicator	Members from age 18 to 40			Members from age 41 to 55		
	Experimental group	Control group	Experimental group	Control group	Experimental group	Control group
Grip(N)	297.92 ± 37.44	265.58 ± 34.30	$P < 0.01$	293.90 ± 26.45	254.80 ± 29.20	$P < 0.01$
Vertical jump(cm)	39.00 ± 7.35	32.80 ± 6.04	$P < 0.01$	/	/	/
Seated body forward flexion(cm)	16.10 ± 6.43	6.30 ± 6.65	$P < 0.01$	14.60 ± 7.15	5.30 ± 5.89	$P < 0.01$
single foot jump with eyes closed(S)	/	/	/	12.45 ± 5.96	7.30 ± 5.84	$P < 0.01$
Sit-up(pcs)	27.46 ± 9.34	12.50 ± 10.15	$P < 0.01$	/	/	/
Reaction time(cm)	/	/	/	11.23 ± 2.86	15.74 ± 4.93	$P < 0.01$

From Table 6 physical quality indicator statistical data, it can know that grip indicator is maximum ability that presented when hands muscle and forearm muscle contract and make exertion, the indicator not only reflects human arms muscle fibril quantities and cross section size, and also reflects nervous adjusting muscle activities ability, data indicates that experimental group is superior than control group; Seated body forward flexion indicator reflects human trunk and waist abdomen, hip ,posterior thigh muscle and ligament extension and flexibility degree, meanwhile it reflects these parts' joint activity range, the indicator data indicates that experimental group members is superior to control group members; Vertical jump indicator is used to measure two legs on spot upwards vertical jump height ,it reflects human lower limbs explosive force ,data indication shows that experiment members are superior to control group; Sit-up indicator is reflecting human waist abdomen strength and explosive speed, it can strengthen the indicator movement ability in aerobics, data indication shows that experiment members are superior to control group; Reaction time indicator is an important physiological indicator that measure human nervous system dynamical reaction speed, is an important sign that measure aging degrees, the quick reaction shows that human nervous system owns good technology status, data indication shows that experiment members are superior to control group; Single foot standing with eyes closed indicator reflects human balance quality, and balance quality is also a kind of complicated comprehensive ability, which is close to human strength, endurance, sensitiveness, coordination, muscle sense and vestibular sense other senses , data indication shows that experiment members are superior to control group.

CONCLUSION

This paper firstly introduced aerobics classification as well as upper limbs basic motions and lower limbs basic motions techniques that provided pace status basis for aerobics players' human rigid-body motion mechanical system model establishment; In paper, according to human owning classified limited particle system and adjacent joints interactions two typical dynamical features, established 16 joints that composed human rigid body model, then on the basis of human rigid body model, it analyzed rigid multi-body dynamical systems' features, and constructed Lagrange rigid multi-body system dynamical model; In order to attract more aerobics amateurs, this paper took body building efficiency feature data as research object, made contrasting analysis of experimental group and control group two groups body shape indicators, physical function indicators and physical quality indicators, it verified continuously aerobics training members have advantages over control group members in each aspect quality by data.

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