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Pommeled horse circle technical movement features research based on three-dimensional video analysis model

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ABSTRACT

With sports undertakings development, athletes' competition has grown fiercer, and training is required to be increasingly improved. Scientific training method is an important premise to improve sports level; the paper combines with biomechanical knowledge and computer technology to establish three-dimensional video analysis model, and makes research on pommeled horse circle's one cycle technical motions, with an aim to find out pommeled horse circle technical motions rules and features so that makes improvement suggestions and improve technical motions levels. At first the paper proceeds with biomechanical features analysis of pommeled horse circle's one cycle technical motions, gets kinematics regularity, and then according to kinematics regularity, it establishes three-dimensional analysis model, extracts required kinematic data by model, and goes ahead with data processing. Finally combine with model data and biomechanical knowledge, it researches on pommeled horse circle's one cycle technical motions, gets conclusions and provides technical motions improvement suggestions that makes contributions to Chinese pommeled horse sport event development.

KEYWORDS

Three-dimensional analysis model;
Biomechanics;
Data processing;
Quadratic fit.

INTRODUCTION

Pommeled horse is one of competitive gymnastics events, it originates from Europe that is first listed as gymnastics event in 1896; in 1980s, pommeled horse has been rapidly developed, difficulty and new motions have been constantly emerged. Chinese athletes and researchers have made lots of contributions to world pommeled horse technical progress, and won world champions continuously for six times. In recent years, with sports undertakings development, athletes' competition has grown fiercer, the paper combines with biomechanics and computer technology to establish three-dimensional video analysis model, with an aim to make contributions to Chinese pommeled horse undertakings development.

For pommeled horse sport event, lots of predecessors carry out each kind of researches with different methods and makes lots of suggestions. Just by these predecessors' constant exploration and pommeled horse athletes' unremitting efforts; it let Chinese pommeled horse sports undertakings rapidly develop. Among them, Ye Xiao-Dong (2010) carried out feature analysis of world gymnastics championship pommeled horse event

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difficulty and new movements, he pointed out that pommeled horse single movement innovative proportion is larger in gymnastics new rules, connection motions innovative times relative reduce, especially for multiple connective movement innovations are also fewer and fewer; in future training, it should improve movement stability, and constant innovate on the basis of movement stability; in training, it should strengthen grasping movement details and increase movement accuracy[1]. Chen Jian(2007) made discussion on gymnastics men's pommeled horse ring circle teaching methods and provided " stage feeling teaching method" let athlete define circle feelings which built good foundation for future training. Liu Yu-Jin (2007) researched on pommeled horse technical training measures and pointed out pommeled horse movement compiling, difficulty and its connection should be skillful, reasonable, novelty, so that adapted to more difficulty movements, big changes, most complex structure features, it should focus on technical compilation and technical innovation in future training and improved technical movement overall coherence.

The paper on the basis of previous research, combining with computer knowledge and biomechanical knowledge to establish three-dimensional video analysis model, and gets kinematic data and makes research. Combine with model data processing result and biomechanical knowledge to research on pommeled horse circle's one cycle technical movements, so that makes technical movements improvement suggestions and improves Chinese pommeled horse training levels.

POMMELED HORSE CIRCLE ONE CYCLE SPORTS BIOMECHANICAL FEATURES ANALYSIS

Sports biomechanics is a discipline that newly-developed in recent years but develops extremely rapid. Especially for sports events, sports biomechanics application is quite widely. The paper combines with sports biomechanics to research on gymnastics events pommeled horse circle movement. The aim is to explain pommeled horse movement kinematic regularity so that improve training methods and improve athletes' training levels.

Pommeled horse circle movement involves widely biomechanical knowledge. Pommeled horse circle movement has theoretical mechanics' rigid body rules static and dynamic features, the paper defines human body vertical axis relative to perpendicular axis tilt angle as nutation angle, vertical axis surrounding perpendicular axis rotational angle is defined as precession angle, and human body surrounding vertical axis rotational angle is defined as spin angle. Ideal pommeled horse circle requires human body to make constant precession with unchanged nutation angle, meanwhile spin surrounding vertical axis toward opposite direction so as to ensure athlete always face to front in sports process[4]. Its main technical features are: take shoulder as axis, turn as umbrella, clamp chest, far away from supporting point, stretch body and spread movement[5].

In order to simplify model and easier to analyze pommeled horse circle movement sports biomechanical features, the paper combines with pommeled horse circle movement's single arm, double arms supporting status, it simplifies pommeled circle one cycle technical movement into four stages as Figure 1 show.

(1) Double arms side support stage: gravity center gradually shifts to left arm, in Figure 1, from the19th side support to the fifth right hand breaking away from right horse ring phase.
(2) Left arm support stage: In Figure 1, from the 5th right hand breaking away from right horse ring to the 10th right hand gripping right horse ring to back support stage.
(3) Double arms back support stage: gravity center gradually shifts to right arm, in Figure 1from10th right hand gripping right horse ring to the 15th left

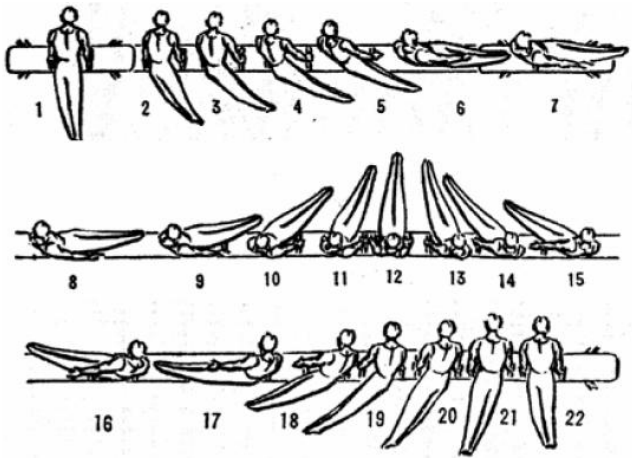

Figure 1: Pommeled horse circle movement decomposition schematic diagram

hand breaking away from left horse ring stage.

(4) Right arm support stage: In Figure 1 the 15th left hand breaking away from left horse ring to the 19th left hand gripping left horse ring again to side support stage.

THREE-DIMENSIONAL VIDEO ANALYSIS MODEL ESTABLISHMENTS

Use two JVC—980videos to continue shoot selected excellent athletes' pommeled horse competition circle whole process, videos locating place is one video in front 10m distance area, the other one in side 7m distance area, so that form into three-dimensional shooting as Figure 2 show, shooting speed is 50 frames per second. And then carry out three-dimensional image handling with shot original images. The paper adopts American RALL sports biomechanical high speed photograph system, combines with human body kinematics 21 joints, 25 segment control points, and photographs shot three-dimensional action scenes, so that achieve above 12000 data. After that combine with sports biomechanics, collect the paper research required data, so that according to data and human body sports mechanical features, makes research on pommeled horse circle one cycle technical movements, explores its rules and features. Its model flow chart is as Figure 3 show.

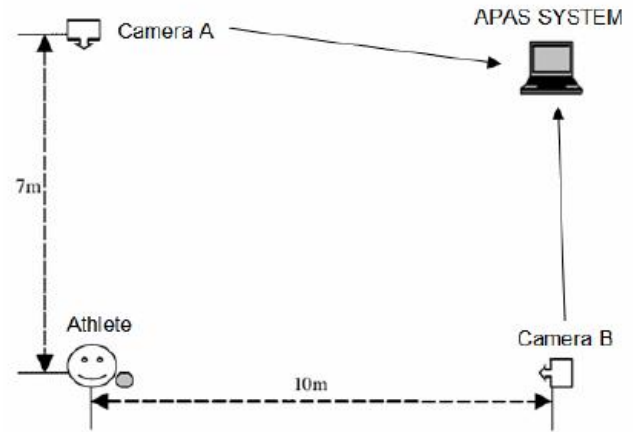

Figure 2 : Three-dimensional shooting site plan view

Among them, subject basic information is as TABLE 1 show.

According to TABLE 1, it is clear that athlete height, weight, age, weight and other physical condition factors and non -training factors have no big differences; therefore the paper assumes that athletes' physical factors have no significant differences on athletes' physical ability training and technical movement playing.

MODEL SOLUTION AND ANALYSIS

Pommeled horse circle one cycle four stages time consumption analysis

By APAS system, extract subject one cycle four stages time consumption data and can get TABLE 2.

According to TABLE 2 data, it can get Figure 4.

By Figure 4, it is clear that pommeled horse athlete

TABLE 1: Subject basic sports status

Competition name	Name	Age	Height	Weight	Sports grade	Years of training
National gymnastics champions in 2007	Lu Bing	29	1.65	59	Master sportsman	24
	Wang Heng	26	1.71	62	Master sportsman	22
	Luo Jing	22	1.65	56	Master sportsman	18
	Yu Si-Yang	19	1.66	60	Master sportsman	15
	Lu Chen-Xi	20	1.64	53	Master sportsman	16
	Chen Chen	20	1.62	57	Master sportsman	16
	Du Wei	21	1.6	60	Master sportsman	17
	Chen Jing	27	1.73	64	Master sportsman	22
National gymnastics champions in 2005	Du Wei	21	1.6	60	Master sportsman	17
	Wang Heng	26	1.71	62	Master sportsman	22
	Guo Wei-Yang	20	1.64	59	Master sportsman	16
National gymnastics championship in 2007	Du Wei	21	1.6	60	Master sportsman	17
	Xiao Qin	23	1.64	55	Master sportsman	18

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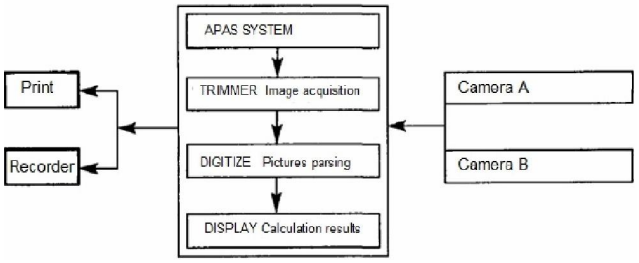

Figure 3 : RALL high speed photograph system flow chart

TABLE 2 : Subject one cycle four stages time consumption

Name	T1	T2	T3	T4	One cycle total time consumption
Lu Bing	0.16	0.32	0.20	0.28	0.96
Wang Heng	0.16	0.32	0.12	0.28	0.88
Luo Jing	0.16	0.32	0.16	0.32	0.96
Yu Si-Yang	0.14	0.34	0.18	0.32	0.98
Lu Chen-Xi	0.16	0.32	0.18	0.32	0.98
Chen Chen	0.16	0.32	0.16	0.28	0.92
Du Wei	0.12	0.28	0.16	0.24	0.8
Chen Jing	0.14	0.28	0.16	0.36	0.94
Du Wei	0.14	0.28	0.16	0.28	0.94
Wang Heng	0.10	0.32	0.16	0.32	0.9
Guo Wei-Yang	0.16	0.3	0.14	0.32	0.92
Du Wei	0.12	0.28	0.16	0.28	0.84
Xiao Qin	0.16	0.28	0.20	0.32	0.96

TABLE 3 : Athlete circle's one cycle each stage time allocation percentage

Name	T1	T2	T3	T4
Lu Bing	17%	33%	21%	29%
Wang Heng	18%	36%	14%	32%
Luo Jing	17%	33%	17%	33%
Yu Si-Yang	18%	35%	14%	33%
Lu Chen-Xi	16%	33%	12%	36%
Chen Chen	16%	33%	12%	36%
Du Wei	17%	35%	17%	30%
Chen Jing	15%	30%	20%	38%
Du Wei	15%	30%	17%	30%
Wang Heng	15%	36%	17%	35%
Guo Wei-Yang	11%	33%	18%	36%
Du Wei	14%	33%	15%	35%
Xiao Qin	17%	29%	21%	37%
Average value	15%	33%	17%	33%
Variation coefficient	12.66%	7.35%	16.29%	8.68%

circle one cycle four stages time consumptions are different, but different athletes has certain rules in same stage time consumption, but time consumptions differences are not big. By Figure 4, it is clear that double arms side support stage average time consumption 0.14 *s* , double arms back support stage average time consumption 0.16 *s* , single arm support (left arm right arm) stage average time consumption 0.31 s . Thereupon, it is clear that pommeled horse athlete circle's one cycle single arm support stage average time consumption is nearly 2 times double arms support stage average time consumption. And due to double arms support stage time consumption is the same, single arm support stage time consumption is also basic the same, and the former time consumption is obvious less than the latter, therefore combine with kinematical knowledge, the paper deduces single arm support stage continue to rotate mainly relies on inertia.

Combine with TABLE 2 each athlete each stage's time consumption to carry out percentage computing, and can get TABLE 3.

In multiple tested athletes, Xiao Qin has a reputation of "The Prince of Pommeled horse". His high technical movement level that no other has, he continued to win world champion in pommeled horse event with absolute advantages in three sessions' world championships. Therefore, his movement data has certain references. By TABLE 3, it is clear that Xiao Qin time consumption percentage in T3 stage is obviously more than others, which shows that extend double hands support stage to increase exertion time is an important factor to improve technical movement. Besides, combine with TABLE 3 variation coefficient can know that variation

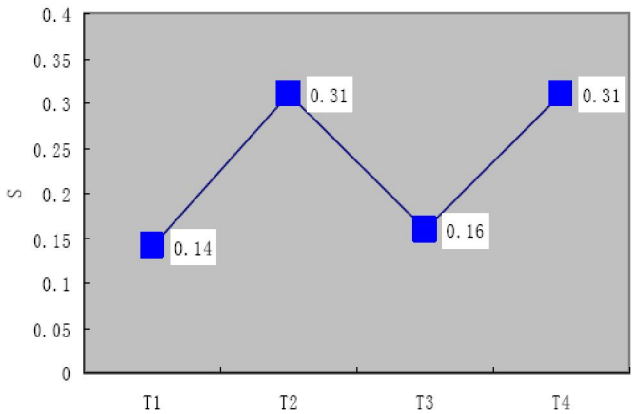

Figure 4 : Circle's one cycle four stages average time consumption

coefficient is larger in double arms support stage, and it is smaller in single arm support stage, thereupon it shows each people exertion degrees differences will cause time consumption larger differences, due to single support stage mainly relies on inertia force, difference is not remarkable.

Pommeled horse circle's one cycle shoulder trajectory planar projection analysis

Figure 5 is obtained by left (right) shoulder trajectory projecting to plane after athlete pommeled horse circling one cycle. By Figure 5, it is clear left(right) shoulder trajectory line is similar to oval, therefore we combine with oval area sizes, and meanwhile according to

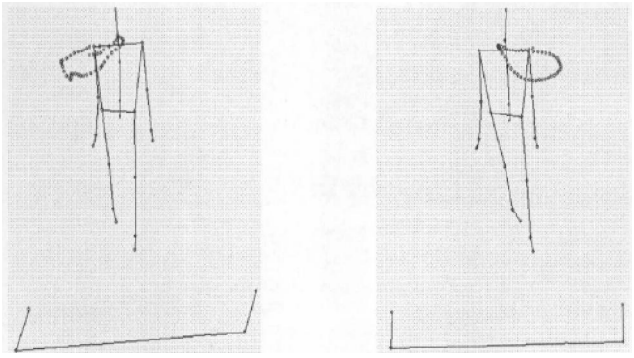

Figure 5 : Lu Bing circle's one cycle left and right shoulder trajectory graph

three-dimensional video analysis model, it can get the similar oval concrete sizes parameters in three-dimensional space: oval frontal axis diameter x, sagittal axis diameter y, and perpendicular axis range z. It further gets each athlete projection oval area(TABLE 4)

Combine with TABLE 4; it is clear that no matter left shoulder or right shoulder, Xiao Qin's area s is far bigger than others. Thereupon, it indicates that his shoulder movement range is larger, projection gets closer to round. So Xiao Qin movement posture is the best, movement completion quality is the highest. In addition, combine with three-dimensional video analysis curve (Figure 5), it is clear that general athletes perpendicular axis range z maximum value appears in side of pommeled horse location. The left hand supports pommeled horse, and right shoulder z value arrives at maximum in right pommeled horse side location.

Pommeled horse circle's one cycle average speed analysis

According to three-dimensional video analysis model, collect each stage group average speed data and get TABLE 5.

The paper makes continuous analysis of average speed, by previous stage average speed to next stage average speed influential relations, it finds out pommeled horse circle's one cycle each stage continuous features, so that strengthen movement continuity. Take $T2$ stage average speed as independent variable, $T3$ stage average speed as dependent variable to make quadratic fitting on data, and find out their function relations, as Figure 6show:

And can get regression equation:

$$V_{T3} = 0.2978 - 3.5136V_{T2} + 17.5138V_{T2}^2 \quad (1)$$

According to formula (1) and Figure 6, it is clear that previous stage average speed has influences on next stage average speed, in training, it should strengthen overall movement coherence grasping so as to let overall movement arrive at elegance, fluency so that get higher result.

Pommeled horse circle's one cycle gravity center liftoff average height analysis

Gravity center high or low has close relations with athletes' completion movement status, the paper takes

TABLE 4 : Athlete circle's one cycle left and right shoulder trajectory projection area table

Name	Left shoulder S	Right shoulder S	Name	Left shoulder S	Right shoulder S
Lu Bing	0.17	0.17	Chen Jing	0.17	0.22
Wang Heng	0.18	0.15	Du Wei	0.13	0.21
Luo Jing	0.16	0.19	Wang Heng	0.21	0.22
Yu Si-Yang	0.1	0.11	Guo Wei Yang	0.17	0.16
Lu Chen-Xi	0.16	0.18	Du Wei	0.16	0.21
Chen Chen	0.16	0.2	Xiao Qin	0.28	0.3
Du Wei	0.11	0.14			

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TABLE 5 : Athlete circle's one cycle four stages average speed

Name	T1	T2	T3	T4
Lu Bing	7.37	6.12	6.24	5.2
Wang Heng	7.34	5.86	7.17	5.88
Luo Jing	6.56	5.71	7.2	6.23
Yu Si-Yang	7.41	6.18	6.5	5.3
Lu Chen-Xi	7.45	6.11	6.6	5.75
Chen Chen	7.45	5.07	7.7	5.27
Du Wei	6.53	6.06	7.15	6.02
Chen Jing	6.43	5.73	7.86	6.1
Du Wei	5.74	5.08	8.1	5.37
Wang Heng	7.15	5.59	7.84	6.11
Guo Wei-Yang	7.76	5.09	7.55	6.4
Du Wei	7.68	5.75	7.43	5.09
Xiao Qin	8.87	5.85	8.24	5.87
Average value	7.21	5.71	7.42	5.74
Variation coefficient	10.69%	7.01%	9.46%	7.66%

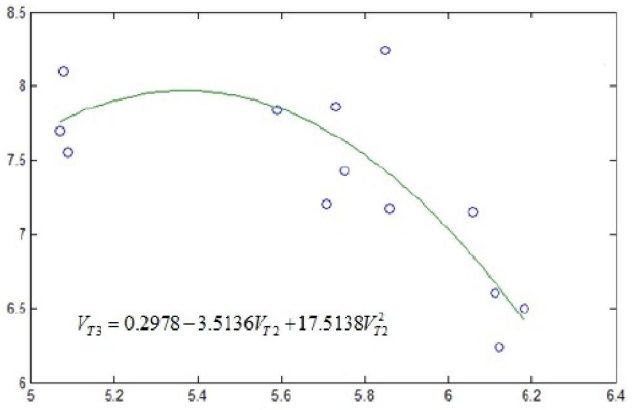

Figure 6 : $T2-T3$ Fitting graph

national gymnastics finals staff in 2007 as research objects, according to gravity center $\overline{D}$ average value computing formula(2)and circle's one cycle D standard deviation σ computing formula(3)and can get TABLE 6.

$$\overline{D} = \frac{\sum_{i=1}^{4} d_i}{4} \quad (2)$$

In formula(2) d_i is every stage gravity center height:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(d_i - \overline{D}\right)^2} \quad (3)$$

Combine with TABLE 6 and can get Figure 7.

TABLE 6 : Athlete circle's one cycle gravity center liftoff average height (m)

Name	Average height $\overline{D}$	Standard deviation σ
Lu Bing	1.392	0.06979
Wang Heng	1.391	0.0274
Luo Jing	1.383	0.03178
Yu Si-Yang	1.384	0.01841
Chen Chen	1.374	0.03048
Du Wei	1.358	0.0556
Luo Chen-Xi	1.349	0.0292

Note: Table 6 name ranks according to final scores from high to low

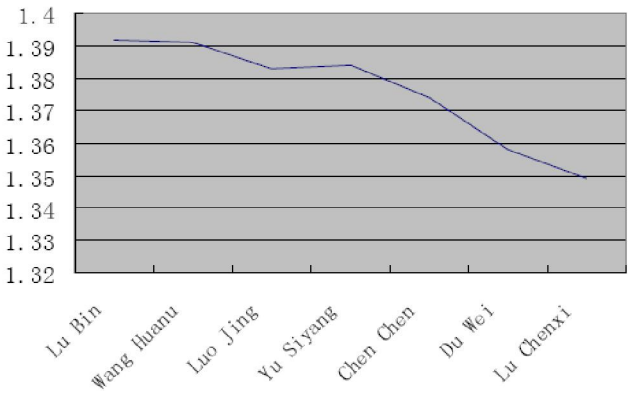

Figure 7 : Athlete gravity center broken line graph

By TABLE 7, it can clearly see that in pommeled horse circle's one cycle technical movement, gravity center liftoff gets higher; athletes' performances would be better that athletes' technical movement gets more elegant and win judger additional score. Therefore athletes should try to improve gravity center height in future training.

CONCLUSIONS

The paper combines with computer technology and biomechanical knowledge to establish pommeled horse circle's one cycle three-dimensional video analysis model, and makes research on computer solving result, it gets physical ability training aspect relative rules and

further makes suggestions, the three-dimensional video analysis model has widely promotion and can promote to other sports events, or used to research on objects sports rules in three-dimensional space; For pommeled horse circle's one cycle technical movement, it gets data by three-dimensional video analysis model and further makes suggestions: Chinese athletes should extend double arms support stage time consumption in future pommeled horse circle's one cycle technical movement training, so that increase exertion time, let movement range enlarge and improve movement appreciation; By pommeled horse circle's one cycle technical movements shoulder, foot trajectory projection analyzing, and combine with mechanical analysis, it can know that athlete's shoulder, foot trajectories projections in plane get closer to round, and then the athlete movement technique gets better. Research on athlete movement gravity center and combine with athlete ranking status, it is clear that gravity center has a positive correlation with athlete ranking, athletes movement gravity center gets higher and then athletes' performance get better. Therefore in future training, it should try to improve gravity center position on the condition not affect movement fluency.

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