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Research Article

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Kinematics analysis of excellent woman shot throwers transition phase techniques based on biomechanics perceptive

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ABSTRACT

Take our country's three excellent woman shot throwers as research objects; apply 3D photography, video analysis and mathematic statistics method to make analysis of kinematics features from right leg land phase to left leg land phase in the aspects of speed, time, and displacement and angle such parameters. The research results show that 3 throwers body gravity center's speed and shots speed has been improved to different extent, but upper body's early lift caused small differences between shot speed and body gravity center speed as well as insufficient equipment exceeding postures; Except for Li Ling, other two members take too long time in transition phase; Except for Li Mei-Ju the other two members take too long knees bending buffer time when left leg landing that effect on the effective use of shots technical complete actions speed rhythm and gliding impulse.

Key words: Female shot, excellent throwers, transition phase, kinematics features

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INTRODUCTION

In 384-322 BC, Aristotle the ancient Greek philosophers and scientists have already observed the mechanic problems of human and animals in daily life. While in late 15 century, Italian scientist Leonardo Di Ser Piero Da Vinci made research on anatomy with human corpse, based on which studied human every posture and movements with mechanics, pointed out human movements should follow mechanics law, that its prototype of sports biomechanics. In 20 century, German Braune and Fisher utilized experimental method of corpse dissection to measure each body part relative weight and gravity center location, and started to research human movements with dynamic method. In 1930s, British physiologist Hill carried out experiments by discharging frog muscle spindle, achieved the famous Hill equation, that is muscle contraction force speed equation by which he gained Nobel prize so that lay the foundation for muscles mechanics [1,2].

On the conference of the 4th international s biomechanics that held in the University of Pennsylvania in1972, sports biomechanics were taken out from biomechanics. Sports biomechanics has been fast developed in recent 30 years while arrived at heyday in 1980s. Except for closely combination with anatomy and biomechanics, sports biomechanics gradually becomes closer to medicine and rehabilitation, its research results level has been greatly improved. Now photography measurement has already developed into 3D high speed video (as America Pea5 system), force test system has already developed into six component force platforms (as Switzerland Kistler system), joint muscles torque test system (as America Cybex system) and so on, that basically form into relative sound and mutual support three large systems as sports, dynamics and electromyography test system. The research content has already extended from strategic services for Olympic Games to Sports competition, while human researches has gradually developed into deepen research on different segments and structure from human mass motion research; and also developed from human mass motions descriptive research into the integration exploring of neuromuscular control as well as sports system and sensory system when exercising [3, 4].

The development level of athletes' strength quality is an important symbol of athletes' physical training level.

Strength quality is called as athletes' basic sports quality. Athletes' every sports quality is indicated through muscles work that based on strength quality. Shot put is proceeding in the circle of 2.135m; it requires throwers with high starting speed, coordination motions and coherence powerfulness. Throwers should have good physical quality, from which strength quality is more important. It is determined by heavy shot equipments and starting shot putting speed. An excellent thrower should put great action force on the shot to make its speed quickly accelerated so as to achieve good results. It requires throwers with not only big muscle contraction force but also fast contraction speed. Therefore, throwers should possess stronger muscle and muscle speed and explosive force, and so the research of how to reinforce is very important.

EXPERIMENTAL SECTION

At present, sports biomechanics is majorly research human internal sports mechanism and external showed human overall mechanism sports features. The key for sports biomechanics theoretical method to easy research is establish human sports model to describe movements. It roughly has two methods, the first method is human system simulation research method, its representative personage is South African mechanics expert Haze; the second method is apply multiple rigid system dynamics theory to establish mechanics model, the representative personage is American mechanics expert Kane. Most mechanics system movements in sports biomechanics research are controlled by Newton law of motion, therefore the models that built is the mathematic form of Newton mechanics system. But Newton mechanics obviously not fit or fully fit for living body, it has already proofed by theory or practice. Therefore, Newton mechanics confronts difficulties in features for muscle, bone and joint system as well as human sports mechanism and overall sports causal relationship solving, and seize human movement behavior biomechanics law physical aspects. Model construction refers to the researched issues model construction on mathematic mechanics analysis. The basic criterion of model construction is representative, simple and practical. Model can be divided into three layers according to its function: descriptive model, interpretative model and predictive model. Mathematic model by far has:

(1) Hanavan human measurement mathematic model;
(2) Santschiw L etc. link collective distribution model;
(3) Zatsiorsky mathematic model;
(4)China human model;
(5) Qiu Ya-Jun and Li Jian-She established human 2D rotation inertia mathematic model.

Research objects

Take top three woman shot throwers in Chinese athletic match that held in Xiao-Shan, Hangzhou in 2008 as research objects, and take transition phase technical motions sports features as main research contents[1](members conditions as Table1).

Table 1: 3 excellent throwers basic condition[2]

Name	year of birth	Height（m）	weight(kg)	Hangzhou best scores(m)
Li Mei-Ju	1979	1.72	101	18.59
Li Ling	1985	1.81	86	18.49
Kong Li-Jiao	1991	1.75	108	18.27

Major research methods

3D photography Method: Adopt spot high speed video images collect and computer hardware recording system equipments to make spot collecting to participant testing techniques images. Optic Lens in high speed video is America PULNIX company CCD high speed scanning video camera(TM-6710Cl), its valid photosensitive area is 5.8mm×4.3mm, dimension of CCD photosensitive component is 9.0μm × 9.0μm； Its valid pixel is 648 (length)×484 (height),shot frequency is 120p/s; exposure time is 1/1000s;high speed collecting card is METEORII-CAMERA-LINK(Canada), main optic axis height is 1.2m, two cameras distance to shooting is 10m, included angle among optic axis is nearly 90°.Before and after match take shot of AIJIE 3D space frame coordinate.

Time and address for shot: in states athletic team training foundations of Xiao Shan, Zhejiang, from April.11th to 13th, 2008

Video analysis method: Use Ariel company's APAS sports analysis system (America) to make analysis of the best scores motion video from six putting that top three throwers did before match, according to human model standard and research requirements select 20 joint points, apply digital filter method to do smoothing to original data, smoothing factor is 6, get the needed parameters original data index.

Mathematic statistics method: Make statistic analysis to selected index and test results with excel, calculate the selected index's mean, standard deviation, and make correlation analysis of index parameters as well as index significant difference testing.

Contrast analysis method: According to needed data that analyzed, make comparison of our country's previous excellent shot throwers (Sui Xin-Mei, Huang Zhi-Hong etc.) with partial foreign excellent throwers' technical motions.

RESULTS AND ANALYSIS

Transition phase body part segments and equipment speed features analysis

Transition phase body gravity center and shot speed features analysis: It can be seen from Table 2 that our country's 3 throwers average value of body gravity center speed in right leg landing is 1.975m/s, that of left legs is 2.244m/s, rising 0.248m/s. In 1990 Beijing national athletics competitions, Huang Zhi-Hong （21.52m）,Sui Xin-Mei(20.63m), their body gravity center speed in right leg landing are respectively 2.03、2.00m/s, while that in left leg landing are respectively 1.91、2.09m/s, difference of body gravity center speed in transition phase are respectively -0.12、0.09m/s.Their average value are reduced 0.015m/s, it indicates Huang Zhi-Hong and Sui Xin-Mei's body gravity speed reduced so as to sufficiently make good equipment exceeding postures before putting, while our country's active-duty three throwers increase body gravity center speed, and trunk dip angle also increase(refer Table4).Research indicates that trunk dip angle has significant correlations with body gravity center speed（γ=0.608,P <0.05）.It shows that the increasing of body gravity center speed has a connection with their upper body earlier lifting .In this way, not only effect on final force exceeding equipments' posture but also shorten shot acting distance.

Table 2: 3 throwers' body gravity center and shot speed parameters in transition phase (unit: m;m/s)

Name	Performance	body gravity center speed R↓	L↓	difference	shot speed R↓	L↓	difference	difference between shot and body gravity center speed R↓	L↓
Li Mei-Ju	18.59	1.99	2.168	0.298	1.96	2.048	0.035	0.143	-0.03
Li Ling	18.48	2.26	2.153	0.117	3.05	2.251	-0.399	0.614	0.97
Kong Li-Jiao	18.27	2.07	2.412	0.33	1.99	2.388	0.148	0.158	-0.08
Average value		1.997	2.244	0.248	2.301	2.229	-0.072	0.305	-0.015
Standard deviation		0.091	0.119	0.094	0.264	0.140	0.236	0.219	0.089

Note： R↓ stands for right leg landing moment； L↓ stands for left leg landing moment

In "human-ball" system, shot speed changes are influenced by human gravity center and trunk dip angle changes. From Table 2, it can be seen that our country's active-duty three shot throwers shot speed from right leg landing to left leg landing has been increased except for Li Ling reduces, the average difference in shot speed is -0.072m/s that Kong Li-Jiao has the maximum difference of 0.148m/s. In 1990 Beijing national athletics competition, Hong Zhi-Hong(21.52m), Sui Xin-Mei(20.63m), shot speed in right leg landing moment are respectively 2.27、2.71m/s, that of left leg landing are respectively 2.26、2.51m/s, transition phase shot speed difference are respectively 0.44、0.25m/s[4].The two's average value reduced 0.105m/s. Both Huang Zhi-Hong and Sui Xin-Mei's shot speed reduced as their body gravity speed, while our country's such 3 throwers shot speed average value increased, due to their upper body earlier lifting together with body twist, undesirable left shoulder backwards swing, not helpful for forming sufficient exceeding equipment posture.

In transition phase, the bigger difference between shot speed and body gravity center speed, the more sufficient throwers' exceeding equipment postures, the bigger shoulder trunk twist force would be generated. The world champion Lisovaskaya as well as excellent throwers Nimeck and Muller's body gravity speed and difference all above 0.8m/s, and their body gravity center speed increased in transition phase [5]. Our country previous excellent throwers Huang Zhi-Hong(21.52m), Sui Xin-Mei(20.88m) difference between shot speed and body gravity center speed in right leg landing moment are respectively 0.17、0.36m/s,that of left leg landing moment are 0.65、0.45m/s[6], average value of the two shot speed and body gravity speed are respectively 0.48m/s and 0.09m/s with 0.039 m/s difference. Combine Table 3 and Table 4, it can be seen that our country three throwers average difference between shot speed and body gravity center speed in right leg landing moment is 0.305m/s, while that in left leg landing is -0.015m/s. Through comparison, we can see that our country three throwers difference between shot speed and body gravity speed has a significant distance far from that of world excellent throwers, its main causes is upper body earlier lifting that led to insufficient exceeding equipment posture.

On a whole, both Chinese and foreign excellent throwers are working hard to improve shot speed and body gravity center speed, which not only increase shot putting overall speed, but also keep shot and human gravity center speed in higher level in the last exertion, that conforms to sports principle. However, some excellent throwers also made good results on the condition that shot speed and body gravity center speed reduced in transition phase, which indicates such condition fit for their own physical ability and technical features, we cannot think their techniques are perfect due to their excellent performance. From the essence of shot putting techniques, transition phase both shot speed and body gravity center speed reduce or only one reduces; such kind of techniques is surely undesirable. If synchronous increase body gravity center speed and shot speed, at the same time complete exceeding equipment posture and form best force posture, they would get more wonderful results.

Transition phase body partial segment speed features analysis: From Table 3, it can be seen that after left leg landing, right hip average speed goes beyond that from left hip(R right hip =1.443m/s,L left hip=1.977m/s), it indicates that left side lower limbs make proactive under thrust toward throwing direction to make preparation for last exertion; Meanwhile, it helpful for hip axis fast moving to throwing direction, further enlarge exceeding to shoulder axis, shoulder basically keeps still at this time to make trunk fully twist and tight and more perfect exceeding equipment motions. Through research, left and right hip speed have significant correlation with body gravity center speed γ right hip =0.48,P <0.05 γ left hip=0.49,P<0.05), and have significant correlation with throwing performance （γ =0.710,P <0.01）,it can be seen that hip motion is the key technique in transition phase[7].Left knee speed rises in previous half phase of transition has a relation with left leg's proactive inserting in front lower direction, due to relative big left knee speed in previous phase, left knee speed is in the rising trend. The more proactive left leg landing, the quicker left leg towards inserting, the quicker transition double supporting would be formed and exceeding equipment posture also easily formed. Therefore, the three throwers total speed rhythm sequence is reasonable.

Table 3:Transition phase hip, knee joint speed parameters(unit: m、m/s)

Name	Performance(m)	left hip speed		right hip speed		left knee speed		right knee speed	
		R↓	L↓	R↓	L↓	R↓	L↓	R↓	L↓
Li Mei-Ju	18.59	1.91	2.01	1.46	1.845	1.26	1.866	2.84	1.71
Li Ling	18.48	2.04	1.85	1.06	2.045	1.71	1.075	2.55	2.49
Kong Li-Jiao	18.27	2.33	2.07	1.81	2.059	1.93	1.622	2.94	2.82
Average value		2.093	1.977	1.443	1.983	1.633	1.521	2.776	2.34
Standard deviation		0.176	0.092	0.306	0.098	0.279	0.3307	0.165	0.465

Note： R↓ stands for right leg landing moment； L↓ stands for left leg landing moment

Transition phase techniques time, displacement and angle features analysis

Transitional step time also is the important kinematics parameters to measure merits of transitional step techniques. The faster left leg landing speed, the bigger force is, the quicker body (including middle part) motion would be, the stronger the strength would be. Combine with Table 4, it can be found that our country's 3 excellent throwers average transitional time is 0.152s, while that of previous foreign excellent throwers are averagely as 0.725s, domestic Huang Zhi-Hong, Sui Xin-Mei, Li Mei-Su best scores' transitional time are averagely as 0.10s[6]. It indicates our country 3 excellent throwers take long time in transition phase. Long transitional long cause human body cannot timely change from gliding into the last exertion, and effect gliding impulse effective use that leads to shot speed and human gravity center speed reduce accordingly, effects technical motions speed and rhythm changes.

In transition phase, double supporting step length has direct influence on the last exertion. When throwers left leg landing, if support step length is too short, left leg cannot resist stop board, and would reduce throwing circle applying, also not help for left leg grounding and generating force, that lead to shot work distance shorten. But if support step length is too long, human gravity center would need to make larger moving that would extend transition time, effect on right leg pedaling and extending as well as left leg trig supporting force, make transition motion cannot timely enters into the last exertion, influence on gliding speed effective use; From Table 4, it can be seen that our country's 3 excellent thrower's support step length average value is 1.136m, our country's previous excellent shot throwers Sui Xin-Mei(21.66m) support step length is 1.10m, and that of Huang Zhi-Hong(21.52m) is 1.24m, Li Mei-Su（20.95m）is 1.14m,Zhou Tian-Hua（20.11m）is 1.08m,Cong Yu-Zhen（19.54m）is 1.12m [7],average value is 1.114m. By contrasting, it can be found that the three excellent throwers two legs width and length have no big difference with that of our country's previous excellent throwers, but it would cause throwing distance loss in this way, therefore it should be improved in training and properly shorten distance between left leg and stop board in permissible range of rules.

Table 4: Transition phase techniques time, displacement and angle parameters(unit: m、s 、°)

Name	Performance	transition phase time	shot resultant displacement	two legs width	landing trunk dip angle R↓	L↓
Li Mei-Ju	18.59	0.183	0.36	1.1	38.26	47.69
Li Ling	18.48	0.092	0.27	1.02	54.16	66.88
Kong Li-Jiao	18.27	0.183	0.4	1.288	32.81	59.64
Average value		0.152	0.343	1.136	41.743	58.07
Standard deviation		0.043	0.054	0.112	9.0574	7.913

Note： R↓ stands for right leg landing moment； L↓ stands for left leg landing moment

From Table 4, the average value of our country's 3 excellent throwers trunk dip angle in right leg landing is 41.743°,that in left leg landing is 58.07°. Our country's previous shot throwers trunk dip angle in right leg landing and left leg landing are respectively Huang Zhi-Hong（21.52m）34.3°and 52.1°； Li Mei-Su（20.95m） 37.8°and 41.8°；Sui Xin-Mei（20.88m）40.1° and 44.2°；Zhou Tian-Hua（20.11m）54.3°and 57°；Cong Yu-Zhen（19.54m）33.8°and 53°, the average value of trunk dip angle in right landing moment is 40.060°, and that in left leg landing is 49.620° [8]. By contrasting, it can be seen that 3 excellent shot throwers compared with previous excellent throwers, their trunk dip angle are so big in transition phase.

The average shot resultant displacement of three throwers is 0.343m, comparing with our country's previous excellent throwers (Sui Xin-Mei[19.29m]shot resultant displacement is 0.21m,Huang Zhi-Hong [21.28m] shot resultant displacement is 0.353m）,no big difference existing, it indicates the three throwers control to right shoulder is reasonable.

Table 5: Transition phase hip, knee and ankle joint angular parameters(unit: m、°)

Name	Performance	right leg landing left hip angle	left knee angle	left ankle angle	left leg landing left hip angle	left knee angle	left ankle angle
Li Mei-Ju	18.59	149.39	107.99	105.58	152.07	129.308	105
Li Ling	18.49	147.9	148.99	113.24	148.38	141.384	116.8
Kong Li-Jiao	18.27	150.63	160.64	96.199	162.49	154.037	73.81
Average value		150.64	139.207	105.006	154.313	141.576	98.537
Standard deviation		2.886	22.58	6.969	5.975	10.096	18.136

Note： R↓ stands for right leg landing moment； L↓ stands for left leg landing moment

Transition phase body segments angle changes also is the important kinematics parameter to measure transition stage techniques merits, reasonable body angle changes can make hip and shoulder such two axis form into fully twist and tight angle, extend muscle groups that engage in the last exertion to the highest limits in advance to establish firm base for sharply and quickly last exertion. In transition phase, left hip angle should be changed in smaller range, left knee angle should be increased while left ankle angle should probably decrease, left leg quickly landing towards stop board internal lower side and quickly form good left side support to further form good side arch, convert gliding horizontal speed into human and shot rotation speed. Our country three excellent throwers left hip angle(refer Table 5), increased 3.673°from right leg landing to left leg landing, from which Li Mei-Ju, Kong Li-Jiao have more increasing; left knee angle increased 2.369°, all correspondingly decrease except for Li Mei-Ju; left ankle angle reduced 6.469°, from which Kong Li-Jiao decreased 22°,only Li Ling increased 3.6°.Hip angle and knee angle increasing indicates that consciously forward extending left leg and enable it landing trigged is helpful to form good left side support, enable gliding horizontal speed convert into human and shot rotation speed. By contrasting, it can be found that Li Mei-Ju speed, rhythm relative techniques is rescannable, her left leg can fast landing supported, other two throwers knees bending buffered after left leg landing, losing speed got from gliding phase so that influence completed techniques speed, rhythm and last exertion effects.

CONCLUSION

Our country's 3 female shot throwers transition phase body gravity center speed and shot speed have been improved to different degree, but their earlier upper body lifting make smaller difference between shot and body gravity center speed as well ass insufficient exceeding equipment postures. Except for Li Ling, other two members take too long time in transition phase that caused untimely and more effectively convert into the last exertion; Except for Li Mei-Ju the other two members take too long knees bending buffer time when left leg landing that effect on the effective use of shots technical complete actions speed rhythm and gliding impulse.

In training, specially improve right leg muscle groups fast speed contraction ability, seize the proper chance of right leg generating force, highlight quick transitional techniques features, shorten transitional time, strive to make fast,

coherent and sophisticated transitional motion .In training, the improvement of body gravity center speed and shot speed should on the premise of ensured forming sufficient and completed exceeding equipment posture. In training, the three throwers should pay attention to solve their problems of too big trunk dip angle. Upper body earlier lifting and left shoulder earlier opening can be avoided through better controlling of left shoulder, left arm as well as press upper body methods.

In conclusion, with improvement of sports competition level and sports training scientific degrees, sports biomechanics research direction would also change from simple human motion techniques analysis into deeper exploration of inner mechanism. With medical science development, orthopedics biomechanics, clinical biomechanics, rehabilitation biomechanics as well as biomechanics in bioengineering would get fast development and gradually become major research fields of international sports biomechanics.

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