



Research Article

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Relative analysis of Taekwondo back kick skills' biomechanics based on 3D photograph parsing

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ABSTRACT

As photographing and video parsing techniques improved, it provides a boost for taekwondo technical researching. This paper make analysis of every stage features of back kick skills by using video parsing data, then based on analysis human gravity shifting features and relative features between hip angle and kick velocity in motion process, through analysis of each link of lower limbs' velocity status in five time phrases, get every links of lower limbs' velocity feature in 4 stages. With the analysis data of taekwondo back kick motions time consuming in 4 stages, get the order of time consuming proportion from biggest to smallest like : the 4th stage> the 1st stage>the 2nd stage>the 3rd stage; it provides theoretical basis to sports analyzing and data references to taekwondo training.

Key words: Back Kick Techniques, 3D Photograph Analysis, Correlation Index, Gravity Displacement

INTRODUCTION

Taekwondo is a kind of kickboxing sport, integrated competition of athlete's intelligence, energy, techniques, skills and willpower as well as others are required to win the game, but the movement core still is the utilization of sports technique, therefore lots of resources are invested to the research of technique motions, while by far the best the studying method is to get every motion of opponents in close range through visual channels, and then decode sports mechanics parameters according to video analysis system. Out of many skilled motions in taekwondo, back kick plays a role in sports score, and this paper is accordingly study the 3D photograph analysis data of taekwondo back kick motion to gain its sports feature.

Many scholars have made efforts in succession to the study of taekwondo and 3D image resolution techniques, provide theoretical basis and experimental platform to their organic integration, and image resolution techniques continuously infiltration to sports analysis, some domestic scholars contribute their own thought and research results. Among them, Zhang Yong [1] Apply 3D image resolution techniques in tracking technical monitoring and analyzing of men and women athletes on 20km train walk at our 29th Olympic games. Chen Yu[2] Started from diagnosis, researching taekwondo crescent kick techniques, find out athletes motions advantage and disadvantage through comparison of two athletes' joint velocity, joint movement trajectory and required time in completing motions; Zhang B. [3] use 3D photography and electromechanically synchronous method, make biomechanics analysis of 8 taekwondo players' on-site back kick motions, get back kick motions data as time, displacement, velocity, gravity changes as well as the residual motions main muscle's original electromyography ,integrated electromyography and every muscle's active order so on other data through 3D photographing, from which the essential traits of back kick technical motion be more deeply, comprehensively revealed ,provide theoretical basis references to taekwondo back kick technical training[4].

This paper , on the basis of previous study, use 3D photography techniques and image resolution system, collect sports parameter and biomechanical parameters of taekwondo back kick technical motion, explore back kick technical motions features through data, provide theoretical basis to sports analysis and scientific guidance.

EXPERIMENTAL SECTION

Measurement techniques and study method

Utilize high-speed photography method to collect and analysis technical motions in sports, and the method has been valued universally by sports researchers. This paper study on taekwondo back kick motion's biomechanical features, provide reliable data for researching.

Measurement techniques: When human body proceeds with quick motion, image recording system should be applied if all motions space features at every moment need to be captured. In sports researching , high speed photography test also do image analysis to human movements, the analysis is composed of 2D and 3D analysis, from which 2D analysis is plane filming, take photos of sports images and define the 2D coordinates of researching objects human body joints by using a high speed camera, calculate relative data's original index as the required displacement, velocity, accelerated velocity, angle, angular displacement, angular velocity and angular accelerated velocity so on through analyzing and smoothing, so as to evaluate sports techniques; While 3D photography and analysis is to take photos of human movements with 2 synchronous high speed camera from different angles, get relative equipment points 3D space coordinates through linear transformation between 2 cameras 2D films, then calculate required displacement ,velocity, accelerated velocity, angular displacement, angular velocity and angular accelerated velocity so on relative index , provide data basis to sports technical feature analysis.

This paper utilize 3D photography and analysis method, use two high camera at frequency of 120HZ to do synchronously shot, take AI JIE 3D radiation space frame as standard frame, adopt American ARIEL sports biomechanics resolution system APAS to analyze videos, do analytical processing by using human body inertial parameter model and select 19 joints to whole back kick motions analyzing based on model's standards and researches, smooth the analytic data with filter method.

Take two high speed cameras to shot fixed equipment 3D video of athletes back kick techniques, one camera located on the front left side 12m next to tester, its height is 1.1m, the other located on the back right 12m next to tester with the same 1.1m height, the principal optic axis intersection angle between such two camera is 120°,athletes eye front foot target, left foot on the front ,right foot on the back, make back kick motion with passwords, foot would finally kick on the center of target, as Fig.1 the test spot overlook schematic diagram shown, A-F in Fig.1 are respectively represents cameras.

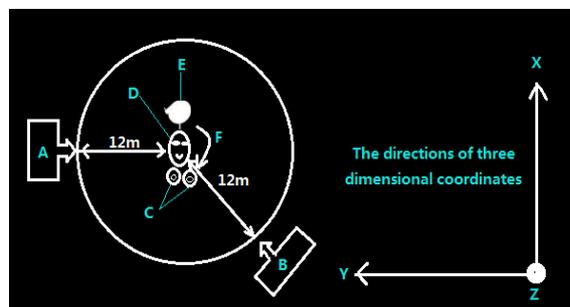


Fig.1: Overlook figures on imaging testing spot

Research Objects and Methods: Research Objects: Select taekwondo domestic master sportsmen and first grade sportsmen total 8 players. In order to easily explanations, express them with P1-P8, the 8 players status show as below Table 1.

Table1: 8 research objects status list

Athletes	Age	Height	Weight	training years	Grade
P1	29	193	100	12	Master sportsmen
P2	21	188	76	4	
P3	21	183	68	5	
P4	23	188	89	8	
P5	22	176	65	6	
P6	19	176	59	4	First grade sportsmen
P7	23	179	72	6	
P8	23	190	100	5	

Research method: Make features analysis to camera's measuring data with mathematical statistics, take 8 athletes every data's average value plus and minus standard deviation to indicate every data features. The computational formula of average value plus and minus standard deviation $\bar{x} \pm SD$ as formula (1) shown.

$$\left\{ \begin{array}{l} \bar{x} = \frac{(x_1 + x_2 + \dots + x_n)}{n} \\ SD = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n}} \end{array} \right. \quad (1)$$

Taekwondo back kick technical analysis

Back kick motions stage division and features: Motions of Taekwondo back kick can be divided into 4 stages as preliminary posture, turn and fold anticipation of body and kicking legs, hip extension and knee extension kicking, fast reduction after kicking. So as to well analysis every items data of taekwondo back kick technical motion, movement process can be divided into 5 time phases and 4 stages again with above 4 stages basis, first phase is the moment that support foot start turning and body turning back, second phase is the moment that kicking foot off the ground and knees start up, the first stage's turning start between first and second phases; third phase is the moment that kicking at minimum leg intersection angle, the second stage's turning and knees up between second and third phase, fourth phase is the moment that leg kicking to the target, the third stage hip extension and knees extension kicking between the third and fourth phases, fifth phase is the moment that kicking legs landing and restoring, restoring after kicking stage between the fourth and fifth phase. The eight research objects time consuming status in 4 states as Table 2 shown.

Table 2: Table of Taekwondo back kick motions time consuming status in 4 stages

Athletes	First stage time consuming	Second stage time consuming	Third stage time consuming	Fourth stage time consuming	Total
P1	0.325 s	0.200 s	0.200 s	0.642 s	1.367 s
P2	0.267 s	0.208 s	0.217 s	0.633 s	1.325 s
P3	0.242 s	0.225 s	0.167 s	0.625 s	1.259 s
P4	0.392 s	0.183 s	0.217 s	0.433 s	1.225 s
P5	0.233 s	0.200 s	0.200 s	0.575 s	1.208 s
P6	0.400 s	0.208 s	0.134 s	0.541 s	1.283 s
P7	0.325 s	0.233 s	0.184 s	0.708 s	1.450 s
P8	0.400 s	0.183 s	0.192 s	0.633 s	1.408 s

Taekwondo back kick is a typical turning and kicking motion, its 4 stages closely connected, requiring better consistency of technical motion, in turning process, head should lead body fast turn and shift body center, fold anticipation between body and kicking legs directly affects back kick's quality; in anticipation process, hip extension and knees up kicking provides larger turning velocity, while in quick kick and fast restoring process, the balance of body center of gravity should be adjusted well. Data in Table 2 indicates that no big difference among 8 athletes back kick motions total consuming time, the average value in the range of 1.316 ± 0.0873 s, the third hip extension and knees up stage out of the 4 stages consume the shortest time, the average value in the range of 0.189 ± 0.0277 s, and the other stages time consuming order from smallest to biggest are Second stage <First stage< Fourth stage, their average values are respectively in the range of 0.205 ± 0.0178 s, 0.323 ± 0.0701 s and 0.599 ± 0.0830 s. It can be concluded from above that time features is more obviously in 4 stages, and the 4 stages average time consuming intuitive status as Fig.2 shown.

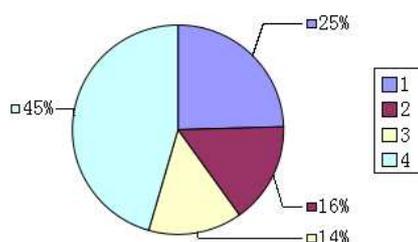


Fig.2: Proportions of every stages average time consuming on totals

In Fig.2, 1-4 are respectively represented as the first stage, second stage, third stage and fourth stage's average consuming time and average total consuming time ratios.

Data in Table 2 indicates that the shortest time consuming in stage 1 is 0.233s from P5, while both P6 and P8 used the longest time of 0.400s, since athletes muscle in different condition after activated in stage 1, some lagging would be happened in transitional gravity shifting process, velocity in this stage therefore has more room for improvement; In second stage athlete P4 consumed the shortest time of 0.183s, while P7 used the longest time of 0.233, body turning in this stage is led by head, fast turning not only shorten eyes away from opponents, but also reflexive accelerate body's turning velocity, inertia thus increased and recover first stage's body gravity center sifting's lagging to some extent; In the third stage, athlete P6 consumed the shortest time of 0.134s, while P4 used the longest time of 0.217s, the kick leg should be folded and closely cling to support leg and make kicking in line in this stage, meanwhile larger turning velocity generated in the turning and hip rotating lead to fast kicking; In fourth stage athlete P4 consumed the shortest time of 0.433s while P7 used longest time of 0.708s, athletes turned two legs supporting of preliminary posture into singular leg supporting in this stage, its bearing areas has been narrowed down, gravity at the moment has been shifted from two legs to singular leg and then change into the front area of singular kicked leg's bearing area, these changes will decrease human body's stability to some extent.

In conclusion, back kick techniques has some characteristics as long fulfilled time requiring, difficult, but the technical motion quite powerful, timing should be mastered in its application.

Human body gravity center variation features in back kick process: In taekwondo back kick technical motion processing, human body changes preliminary posture of legs support into singular leg support, human body's gravity line shift from legs middle area to singular leg, then into the front of kicked leg supporting area. Instability of gravity in back kick processing shown as displacement shifting distance, gravity centers displacement variations can be got from 3D photography and video analysis, as it shown in Table 3 human gravity location variation status.

Table 3: Table of Human gravity coordinates displacement variations in Taekwondo back kick processing

Athletes	X axis displacement variations	Y axis displacement variations	Z axis displacement variations
P1	0.74	0.29	0.003
P2	0.58	0.07	0.002
P3	0.57	0.07	0.002
P4	0.66	0.13	0.007
P5	0.51	0.02	0.028
P6	0.67	0.04	0.059
P7	0.39	0.07	0.036
P8	0.65	0.48	0.002

Three directions displacement variation's changing tendency can be got from Table 3's data, as Fig.3 shown.

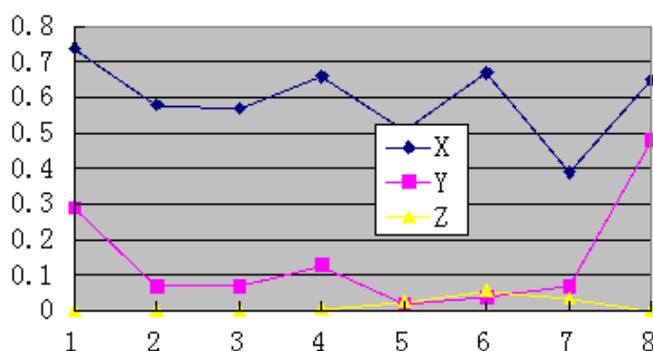


Fig.3. Displacement variations in 3 coordinate directions

In Table 3, X axis and Y axis gravity displacement variations represents gravity center's horizontal versus vertical displacement range, athlete P1 gets the largest displacement variations of 0.74m in X axis while P7 gets the smallest ones of 0.39m. Though individual differences existing among 8 athletes gravity center in movement direction, displacement in movement direction is surely the overall trend of taekwondo athletes back kicking process, legs support-->turning singular support-->forward after kicking, Athlete P8 gets the largest displacement variations of 0.48m in Y axis while P5 gets the smallest ones of 0.02m. It can be seen that individual differences existing on athlete's horizontal displacement in Y axis. Since average value fluctuates inside the range of ± 0.04 , better stability here can be concluded in back kicking, direct leg moving and necking, abdomen stretching, hip abduction are

helpful to effective kicking in back kick techniques. Athlete P6 gets the largest displacement variations of 0.059m in Z axis while both P3 and P8 gets the smallest ones of 0.002m. It can be seen that larger fluctuation in average value of athletes gravity center rising. However, body can be straighten to turned, knees up, hip contracting, finally into shoulder withholding, hip extension, knees extension in taekwondo back kick technical motions, less up and down changing on athletes gravity centers is required to keep body stability in this process.

In conclusion, the whole back kick techniques movements should keep dynamic stability of gravity center so that more helpful to ensure kick strength and velocity.

Relative performance analysis of hip rotation and back kick foot velocity: The most basic symbol to show taekwondo back kick technical motions efficiency is the valid scores, legs fast; correctly, powerfully kicking to opponent score position is required to get such valid scores. The larger velocity kicking leg generated in kicking, the better efficiency in back kicks. In back kick turning process, hip joint produces a larger turning angular velocity, the faster angular velocity got, and the larger kicking velocity would be got from kick leg. In order to make a more accurate research on hip rotation and kick leg velocity, this paper collect 8 athletes kick leg's velocity value and hip rotation angular velocity value in the kicking moment to study the relationship between translational velocity and angular velocity, as Table 4 shown.

Table 4: Data list of hip rotation angular velocity and kicking leg velocity

Athletes	kicking leg velocity	hip angular velocity
P1	1.470 m/s	254.434 deg/s
P2	1.368 m/s	297.432 deg/s
P3	1.399 m/s	207.305 deg/s
P4	2.083 m/s	325.019 deg/s
P5	2.190 m/s	490.242 deg/s
P6	3.510 m/s	253.077 deg/s
P7	2.893 m/s	856.215 deg/s
P8	1.609 m/s	232.254 deg/s

Given hip angular velocity the independent variable ω , while foot velocity as dependent variable v , scatters image representation between the two as Fig.4 shown.

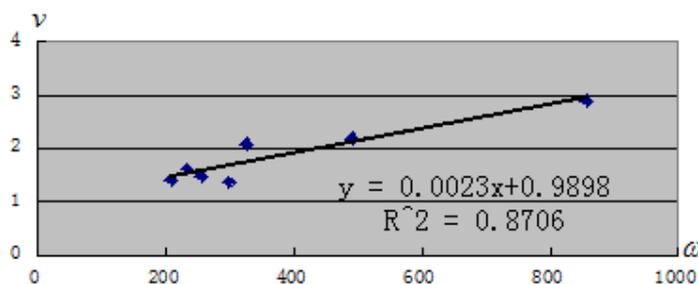


Fig.4: Relation Image between Hip angular velocity ω and kicking leg velocity v

The computational formula of correlation index r of $\omega-v$ data as formula (2) shown.

$$r = \frac{\sum_{i=1}^8 (v_i - \bar{v})(\omega_i - \bar{\omega})}{\sqrt{\sum_{i=1}^8 (v_i - \bar{v})^2 \cdot \sum_{i=1}^8 (\omega_i - \bar{\omega})^2}} \quad (2)$$

Relative index r is calculated out that is equal to 0.9331, it indicates $\omega-v$ obviously correlated, that is to say when angular velocity hip increased; kicking legs velocity would be increased accordingly.

Back Kick motion's lower limbs joint speed features: In taekwondo back kick movements, lower limbs every segments speed constantly spread from near side to far side, though energy loss would be generated in the spreading process, according to angular momentum conservation law, it can be acknowledged that in case near side segments owns high quality, far side ones owns lower quality, the final velocity of far side normally would be increased. In

foot's back kick process, near side segments is thigh, next one is shank, while far side segment is foot. Followed by segments point increasing, its quality become more and more lower, therefore foot velocity begins to spread since large segments, so that the hip and knee speed changes in back kick technical motions have great effect on foot final speed. So as to explore segments speed in each phase, 3D photography and analysis method are applying in collecting 5 phases hip, knee and foot instantaneous speed on this paper, as shown in Table 5.

Table 5: Table of lower limbs velocity in every phase

Lower limbs segments	First phase	Second phase	Third phase	Fourth phase	Fifth phase
Hip	0.81 ± 0.09	2.14 ± 0.36	1.98 ± 0.06	0.68 ± 0.03	0.91 ± 0.03
Knee	0.20 ± 0.04	2.01 ± 0.19	6.24 ± 0.18	1.18 ± 0.07	1.11 ± 0.04
foot	0.31 ± 0.05	2.06 ± 0.16	8.93 ± 0.27	2.07 ± 0.08	0.95 ± 0.01

Distribution features of every lower limbs segment in five phases as Fig.5 shown.

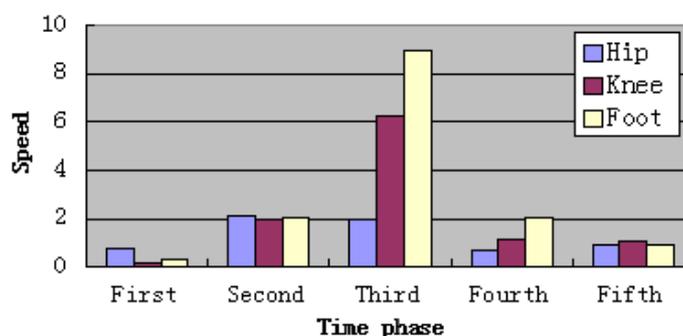


Fig.5: every segments velocity features in 5 phases

It can be concluded from Fig.5 that hip speed arrived largest in second phase, and the second stage keeps approximate maximum speed while the fourth phase get the lowest speed. In the 5 phase speeds, except for first phase starting turning speed faster than other segments, hip speed in other phases all lower than other segments; knee and foot speed all reach the fastest in the third phase, while be slowest in first phase, both of them increased in first and second phases, started to decrease since the third phase, knee from the two has slightest speed changes in the fourth phase, while foot speed decreased in the fourth phase; the three segments have roughly the same speed in the second and fifth phase.

CONCLUSION

On the basis of research on taekwondo back kick technical motions measurement techniques, utilize 3D camera principal, provide scientific layout planning to test sites; This paper select 8 taekwondo athletes as research objects, four of them are country's master sportsmen while other 4 are first grade sportsmen, and indicate the athlete's body parameters, present data handling method, provide computational formula of using average value plus and minus standard deviation. Make data analysis of taekwondo back kick motions time consuming in 4 stages, get the order of time consuming proportion from biggest to smallest like: the 4th stage> the 1st stage>the 2nd stage>the 3rd stage; Human gravity centers variable status in taekwondo back kick technical motion process were studied, importance of gravity centers stability and its displacement variables root cause were analyzed. Hip rotation angular speed and foot speed relations were studied, obvious correlation ship between the two were found through data, that is when hip rotation speed increased, foot speed would also be increased accordingly; Hip, knee and foot these three segments speed status in every phases were analyzed, every segments speed variable tendency and its feature in 4 stage were concluded.

This paper is biomechanics analyses of taekwondo back kick technical motion, scientific measurement site as well as excellent level and quality research objects were designed, implementation process of mathematical statistics method also was provided so as to get reliable mechanical parameters.

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