HOW WE APPLIED SPORTS BIOMECHANICS TO THE PREPARATIONS FOR THE OLYMPIC GAMES

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INTRODUCTION: Sports biomechanics in China was started in 1959 when a textbook entitled "Sports Biomechanics" by Donskoi was introduced to China from the former Soviet Union during the first ever workshop of sports biomechanics. The first sports biomechanics research laboratory was established in China Institute of Sport Science. Since then, most of the institutes and departments of physical education in China have opened sports biomechanics courses while many provinces have established their own sports biomechanics laboratories. The Ministry of Education made sports biomechanics a required course for physical education majors in 1980, and officially published the required contents of sports biomechanics courses for physical education majors in 1985.

The interests of major funding sources for research in China and the support of the Chinese government were mainly in applied research in the last two decades. Applied research has gained much more recognition than basic science research. Although the Chinese government has increased its investments to basic science research in the last several years, there is still a lot of work to do to fill up the gap in the level and quality of basic science research between China and other well developed countries in the world. Sports biomechanics in China as a scientific research area is in the same situation as other scientific research areas in China.

Currently, basic science research in sports biomechanics in China is mainly focused on the following areas:

- Anthropometry, represented by studies on measurements of the human body inertial parameters using CT techniques
- Biomechanical modeling of human body motions, represented by studies on the characteristics of the flow field surrounding swimmers
- Biomechanical properties of skeletal muscles, represented by studies on the constitutive equation of the skeletal muscle contraction
- Biomechanics of sports injures and rehabilitation, represented by studies on the wrist injures of baseball throwers
- Computer simulation of sports techniques, represented by studies on the somersault and twist techniques in diving
- Neuro-network theories and methods for sports technique analysis
- Kinematic, kinetic, and EMG data collection techniques for sports technique analysis

These basic science studies are only a small portion of the research in sports biomechanics in China. It is very difficult for biomechanists in these areas to have significant breakthroughs because of the limitations in scientific techniques.

In contrast to the basic science research in sports biomechanics, applied research in sports biomechanics has been obtained broad recognition in China because of the need of this kind of research in competitive sports in China. Chinese athletes and coaches have found that they need biomechanists to support their training for the Olympic Games and other international competitions. Applied biomechanical research, focused on training, is commonly accepted by Chinese athletes and coaches in a variety of sports, and has obtained sufficient funding from a variety of funding agents.

Currently, applied sports biomechanical research in China is mainly focused in the following areas:

- Sports technique analysis (diagnosis, optimization, and simulation)
- Dynamic measurements and analysis of sports techniques and muscle forces
- Bioelectronic measurements and analysis of the neuromuscular system
- Sports injuries

The research techniques used in these areas include

- Image analysis,
- Force analysis,
- Bioelectronic signal analysis,
- Biomechanics theoretical analysis.

In this presentation, I will introduce some applied biomechanical research we did in assisting Chinese athletes for preparing for the Olympic Games and other major international competitions.

BASIC CONSIDERATIONS AND EXPERIENCES: Athletes and their coaches are the center of competitive sports. Applied biomechanical research and services play a supporting role in sports training. We believe that the applied biomechanical research and service in china assist athletes and coaches in training in the following areas:

1) Effects of training on the improvements of techniques in specific sports
2) Improvement of training methods
3) Scientific foundation of the control of sports training
4) Scientific training

The main goal of Chinese elite athletes' training is to prepare for the Olympic Games and major international competitions, and further more, to have their best performances in those competitions. To achieve this goal, elite athletes' training has to be individualized. Individualization is the key to successful training of elite athletes. Most of the biomechanical questions regarding the training of elite athletes are related to the individualization of training. To meet the need of individualized training for specific elite athletes, applied biomechanical research and services should have the following features:

1) Long term, systematic, and event specific.
2) Focused on specific training questions.
3) Scientific, simple, and effective monitoring and diagnosis.
4) Quick feedback, and on site services.
5) Simple, repeatable, and comparable graphics.
6) Meaningful predication and suggestions.

Deviation from these features would negatively affect the trust of athletes and coaches in sports biomechanists, their collaboration with sports biomechanists, and the funding to applied biomechanical research and services.

The applied sports biomechanical research and services for Chinese elite athletes are rooted in the practices of training. Our applied research and service systems are shown in Figure 1.

Whether this applied biomechanical research and service system can effectively solve the problems in actual training is a frequently asked question, which draws Chinese sport biomechanists' attention. The implementation of this system can be divided into three phases: (1) research phase, (2) feedback and validation phase, and (3) control and adjustment phase (Fig. 2).

Sports training is complicated, multiple factor, dynamic, and individualized process. The biomechanical questions raised by athletes and coaches regarding sports training are aparently event specific. Therefore, the detailed methods and techniques we used to implement our applied biomechanical research and service system in specific sporting events are also event specific. The following examples serve as demonstrations of our event specific applied biomechanical research and services.

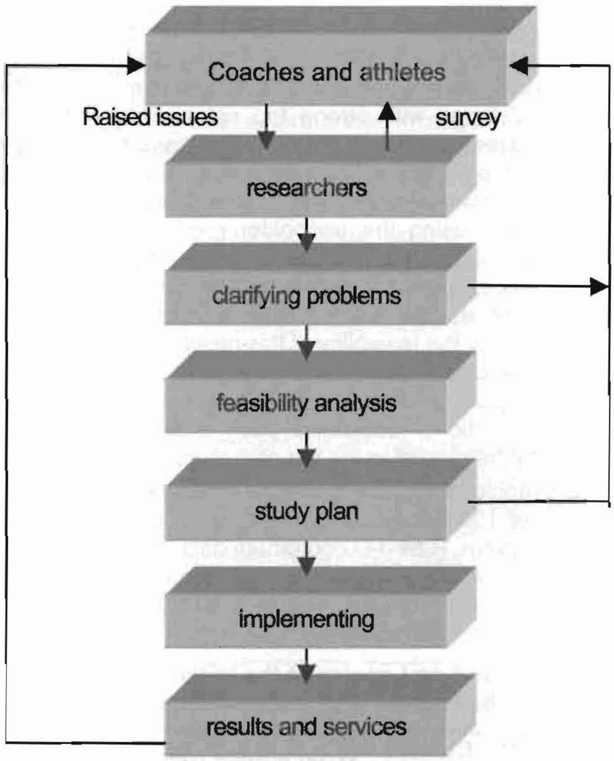

Figure 1 **A model for applied biomechanical research and services**

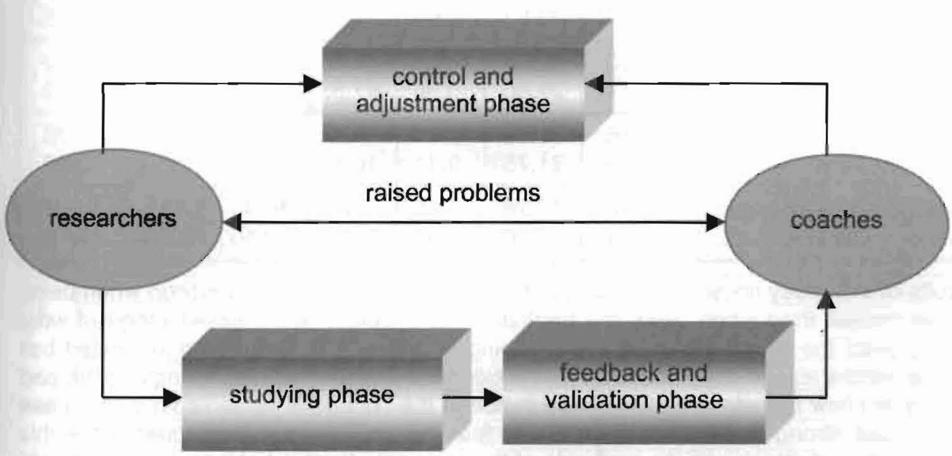

Figure 2 **Basic process of applied biomechanical research and services**

THE APPLICATION RESEARCH AND SERVICE OF TABLE TENNIS:

The Development of the Backhand and Backside Techniques with Penholder Grip in Table Tennis (Shaofa Xu, Huanqun Wu, Bing Yu, et al)

In the early 1980's, Chinese table tennis players' traditional backhand pushing technique was challenged by the European players' loops with strong top spins, The Chinese players' traditional push attack strategies for players using the penholder grip has obvious weaknesses in counter attacking loops with strong top spins due to the constraints of the anatomy of the arm. In order to solve this problem, the Chinese Table Tennis Team designed a new backhand attaching technique strategy for players using the penholder grip. This technique allows players using penholder grip to hit the ball with the backside of the pad to improve the control and power of the backhand attack. This technique is called the penholders' stakeholder play, The feasibility of this technique had to be studied before it could be formally recommended to elite Chinese table tennis players. To study the feasibility of this new technique, we conducted an experimental study to compare the critical technical parameters between the new and traditional techniques. The subject in this study was an elite table tennis player who had over six years experience of using the traditional backhand push attack technique with the penholder grip before the experimental training of using the new technique for three years.

Three-dimensional (3-D) cinematographic data were collected using two synchronized EPL high speed cameras at a frame rate of 100 frames/second. Critical body and pad landmarks were digitized using a GP-2000 film digitizer. Raw 3-D coordinate data were smoothed. Critical biomechanical parameters of the backhand attack against top spin loops were determined and compared between the new and traditional techniques. Table 1 shows the major results of this study.

Table 1 Upper extremity joint angles and pad angles at the initial contact of the ball with the pad, and maximum ball speed with different techniques

Technique	Shoulder Angles (deg)	Elbow Angles (deg)	Wrist angles (deg)			racket angles (deg)	Max. velocity (m/s)
			α	β	γ		
Backside push	28.10	10.75	0.42	18.36	21.10	68.00	9.46
Backside flip	35.12	23.81	0.65	31.75	36.20	65.80	14.35
Backside whip	44.80	15.20	0.63	36.41	41.50	51.10	15.69
Backside loop	43.74	21.80	0.36	47.52	30.10	60.80	16.70
Backhand push	35.76	35.56	0.61	7.30	6.10	71.90	12.00
Backhand power push	22.90	21.75	0.71	10.90	12.40	72.50	10.52
Backhand side spin push	47.46	73.28	1.06	8.90	16.40	68.10	12.99
Backhand loop	17.24	23.20	0.69	30.10	19.10	70.50	15.71

The results of this study show that the player had a greater range of wrist motion when using the new technique than when using the traditional technique. The increased range of wrist motion improved the effectiveness of the whipping motion of the arm, which increased ball speed. The results also show that the player reduced the forward inclination angle of the pad when using the new technique which should increase the control of the top spin loop. These results provided strong scientific support to the feasibility of the new techniques. After this study, the backhand attack with the backside of the pad using the penholder grip was formally introduced to Chinese elite table tennis players, and became a weapon for the Chinese Table Tennis Team to win medals at the Olympic Games and other major international championships.

Techniques and the Spin in Table Tennis (Huanqun Wu, Zhifeng Qin, et al)

Speed and spin are two important elements in table tennis. The close table fast attack and the variety of spins from slice allowed Chinese table tennis players to reach and remain at the top level of the world in the 1960's. In the 1970s', the European table tennis players developed loop techniques and challenged the elite positions of Chinese table tennis players. The traditional techniques and tactics of Chinese table tennis players lost their advantages. Table tennis techniques and tactics have been moving toward a combination of speed and spin since the 1980's. European players rely more on spin, while Asian players rely more on speed. Both types of players had great performances in major international competitions while neither showed clear advantages. In this situation, Chinese table tennis players and coaches would like to know the spin speed of the ball with different techniques, so they could develop new techniques and tactics to use against European players. To answer this research question directly from players and coaches, China Institute of Sport Science conducted a study on the spin speed of a table tennis ball with different techniques.

We recruited 24 elite table tennis players, including 12 players from the Chinese National Team, and 12 players from the Chinese Junior National Team. Among these players, there were six players playing loops using the chop knife holder grip, two players playing loops using the penholder grip, three players playing fast attacks using the penholder grip, and 1 player play slice using the chop knife holder grip from each team.

A PD-1 ball rotation measurement system was used to measure the table tennis ball's rotation speed. The PD-1 ball rotation measurement system consists of an optical image detector, a high speed scanner, an optical signal processor, and a computer that controls the entire system. The system has a 0.75 m × 1.05 m calibration field, in which it can measure the rotation speed of a ball between 20 and 200 r/sec with an uncertainty rate less than 3%.

The techniques we tested are listed in table 2.

Table 2 The main content of the test

Tactics	Techniques
Loop	High loop, fast loop, chip, serving, etc
Fast attack	Mini loop, lash, chip, serving, etc
Slice	High loop, fast loop, chip, slice, power slice, serving, etc

Table 3 is a part of the results from this study.

Table 3 Spin speed with different techniques (revolutions/sec)

Technique (sample size)	Average	Standard	Maximum
Chinese Table Tennis Team			
Loop (12)	128.4	7.6	145.3
Fast loop (12)	134.9	8.4	151.3
Slice (3)	65.5	9.0	84.8
Chip (12)	55.6	7.6	74.4
Chinese Junior Table Tennis Team			
Loop (11)	126.7	8.3	143.5
Fast loop (11)	131.2	9.1	149.1
Slice (3)	57.2	13.5	85.8
Chip (12)	50.3	10.8	72.0

Most players had a greater top spin speed in fast loop drives than in high loop drives. This result indicates that those players had some technical problems in their high loop drives and might need to increase the quantity and quality of their high loop drive training.

The results also show that the pads with pimple-in sandwich rubber surface, and the pads with pimple-out sandwich surface produced a similar ball speed, but the pads with pimple-in sandwich rubber surface produced greater ball spin speed than did the pads with pimple-out sandwich rubber surface. The results further show that grip style had no significant effects on ball speed and spin speed. Finally, the results show that the absolute ball spin speed in slice was lower than that in loop, but similar to that in drive with pimple-out pad.

These results provided significant scientific information for coaches and players to develop new techniques and tactics against European players' loop, and training programs for preparation for the Olympic Games and other major international competitions.

Effects of Table Tennis Ball Size and Mass on Ball Speed
(Xiaopeng Zhang, Huanqun Wu, et al)

Modern table tennis as a sport has been developed to such a point that the high speed and strong spin have significantly reduced the length and number of rallies for each point. It has been noted that the population of table tennis fans has been declining in the last two decades. It is difficult for people to appreciate complicated techniques because of high ball speed. Decreased public interest led to decreased financial support to table tennis as a sport because of decreased television and other media coverage. Experts in table tennis have realized that a reform is needed to keep this sport alive.

The International Table Tennis Federation (ITTF) has made many major changes to competition rules in order to enhance the reform of table tennis. For example, the new rules require that the two sides of the pad have to be in two contrasting colors if they have different types of rubber surface with different properties. The new rules also allow balls in white and yellow, instead of white alone. Further, the new rules set additional restrictions to serving. These rule changes, however, did not significantly slow down table tennis matches and increase public interest in table tennis. Under this circumstance, the ITTF proposed to increase the diameter of table tennis ball from 38 mm to 40 mm in an attempt to reduce the ball speed and spin, and increase rally length for each point in matches. This proposed change in rules might assist in drawing public interests in table tennis back, if it could effectively reduce the ball speed and spin and the overall speed of matches. This proposed change might also cause significant changes in table tennis techniques and tactics. At the request of the ITTF, China Institute of Sport Science conducted a study on the effects of table tennis ball size and mass on its speed and spin to provide scientific evidence for the proposed change in rules.

The subjects in this study were three elite Chinese table tennis players. The PD-1 ball rotation measurement system was used to measure speed and spin of table tennis balls with different diameters and masses. A stationary cine camera was used to collect two dimensional (2-D) trajectories of the table tennis balls at frame rate of 120 frames/sec. The camera was placed perpendicular to the plane of the ball trajectory. The PEAK Performance Motus system (Peak Performance Technology, Englewood, CO) was used to digitize the trajectories of the table tennis balls.

Table 4 and table 5 are the main results of this study. The main results of this study show that the speed and spin speed of the ball 40 mm in diameter were 13% and 21% lower compared to the ball 38 mm in diameter and similar mass. These results suggest that increasing ball diameter to 40 mm from 38 mm would reduce the overall speed of table tennis matches and increase the length of rallies for each point, which may assist in achieving the ITTF's goal to increase spectators' appreciation for table tennis matches.

Table 4 Effects of ball mass and diameter on ball speed in forehand power drive

Ball	Diameter (mm)	Weight (g)	n	Mean Speed (m/s)	SD	T	p	Reduction Rate (%)
A	38	2.51	9	17.8	1.2	1.9 (A *vs* B)	>.05	4 (B *vs* A)
B	40	2.79	9	17.0	0.4	7.6 (B *vs* C)	<.05	9 (C *vs* B)
C	40	2.49	9	15.4	0.5	5.6 (A *vs* C)	<.05	13 (C *vs* A)

Table 5 Effects of ball mass and diameter on spin speed in Loop (revolutions/sec)

Ball	Diameter (mm)	Weight (g)	n	Mean Spin Speed (m/s)	SD	T	p	Reduction Rate (%)
A	38	2.51	8	133.5	8.4	3.5 (A *vs* B)	<.05	13 (B *vs* A)
B	40	2.65-2.80	11	116.5	11.5	1.8 (B *vs* C)	>.05	10 (C *vs* B)
C	40	2.40-2.53	5	105.8	9.2	5.6 (A *vs* C)	<.05	21 (C *vs* A)

This study provided the ITTF with significant scientific information to support the proposed change in ball size. Based on the results of this study, the ITTF decided to formally change the diameter of official table tennis ball from 38 mm to 40 mm in diameter on October 1st, 2000. At the same time, based on the results of our study, Chinese table tennis players and coaches started developing new techniques and tactics, and had great performances at the Olympic Games and major international competitions after the rule changes.

APPLIED BIOMECHANICAL RESEARCH AND SERVICES FOR MEN'S HURDLES IN TRACK AND FIELD (TING LI, AI-DONG LI, TINGGANG YUAN, ET AL): The Chinese Track and Field Tem had several elite hurdlers in the last few years, such as Liu Xiang (110m Hundle Gold Medalist of 2004 Olympic Games) and Shi Dongpeng. Of these new elite hurdlers, Liu Xiang showed great talent and potential in his training and competitions, which brought excitement to track and field in China. To prepare Liu Xiang for 2004 Olympic Games, the China Athletic Association formed a research and service team for the men's hurdle events in 2002. The main task of this team was to perform research, and provide services based on the questions coaches had in preparation for the 2004 Olympic Games in Athens. An important part of this team's work was the technique analysis for Liu Xiang. Mr. Ting LI, Mrs. Aidong Li, and Mr. Tinggang Yuan from China Institute of Sport Science were assigned to this job. They have applied biomechanical methods in their applied research and service in collaboration with Coaches since 2002.

The research and service team realized that what the coaches and athletes need is quick, visualized, realistic, and simple feedback, not complicated mathematic models and quantitative data. Accordingly, the team decided to use qualitative analyses to provide routine service, and quantitative analyses to provide supporting information. The basic service model was:

Research on literature and documents

⇩

Discussions with coaches

⇩

On site videotaping and imaging feedback

⇩

Imaging process and quantitative analysis

⇩

Conclusive feedback

⇩

Discussions with coaches

⇩

Preparing for further research and services

Videography and image analysis were the major techniques used in this study. The major pieces of equipment used in this study were digital video camcorders with a frame rate of 25 frames/sec (50 fields/sec). Video analysis systems used in this study include the Engine Motion Analysis system, the SIMI Motion Analysis system, and DARTFISH Motion Analysis system.

In our applied research and service work for hurdlers, the study on monitoring the structure of hurdling time, simulation and reinforcement of running rhythm between hurdles, and image processing and feedback were most appreciated by coaches and athletes.

Simulation and Reinforcement of between Hurdle Running Rhythm

The between hurdle running rhythm is one of the factors that affects hurdlers' performances, in which coaches show great interest. To reinforce Liu Xiang's long term memory of the rhythm of his fastest between hurdle run, we cut the video clip of his shortest between hurdle run, and edited it as a video clip of ten consecutive between hurdle runs. We also added the audio signal of Liu Xiang's running rhythm of his fastest between hurdle run to the edited video clips. The edited video clips with audio rhythm signals were repeatedly played to Liu Xiang as a multi-media training program to reinforce his memory to the rhythm of his fastest between hurdle run.

Processing Video Image for Technical Information Feedback

Immediate replay of technical video images is one of the ways for athletes and coaches to effectively understand sports techniques and training effects. In our service program, we have been providing systematic quick video feedbacks with multiple images to athletes and coaches. The video imaging techniques we used for comparing sports techniques include stacked video images, superimposed video images, fade away video images, and continuous and individual image print outs. These technical information feedbacks were greatly appreciated by the coaches and athletes.

STRENGTH ANALYSIS: In preparation for the Olympic Games, Chinese elite athletes and their coaches repeatedly asked us to provide strength analysis to assist them in improving athletes' general and event specific strength. To meet this request from athletes and coaches, we created a special measurement system to analyze the required muscle strength for a given athlete in a given sport (Fig.3). This system has been successfully applied in the training of Chinese elite swimmers.

Fast starts and turns are important for good performance in swimming. Increasing starting and turning speeds has been a way for elite Chinese swimmers to improve their performance. The starting and turning speeds in swimming depends on swimmers' techniques, coordination, and strength. Event specific strength is essential among these factors. The event specific strength that affects a swimmer's starting and turning speeds is mainly lower extremity event specific strength. How to find weaknesses in swimmers' lower extremity event specific strength, and effectively improve swimmers' lower extremity event specific strength to increase their starting and turning speeds was a question Chinese swimming coaches frequently asked in preparation for 2000 Olympic Games.

We learned from coaches that the key of the starting and turning techniques in swimming is the coordination of the hip, knee, and ankle joint motions, and that the hip and knee extension plays a major role in starting and turning. The hip and knee extensors need to have great power for fast a start and turn.

We can comprehensively evaluate a swimmer's extension power of the lower extremity kinetic chain by measuring and analyzing the power of the entire lower extremity extensor groups as well as the power of the extensors of individual joints. Comparisons of lower extremity extension power characteristics between swimmers can reveal the weaknesses of individual swimmers in lower extremity extension power, so, individualized specific strength training programs can be developed for any given swimmer.

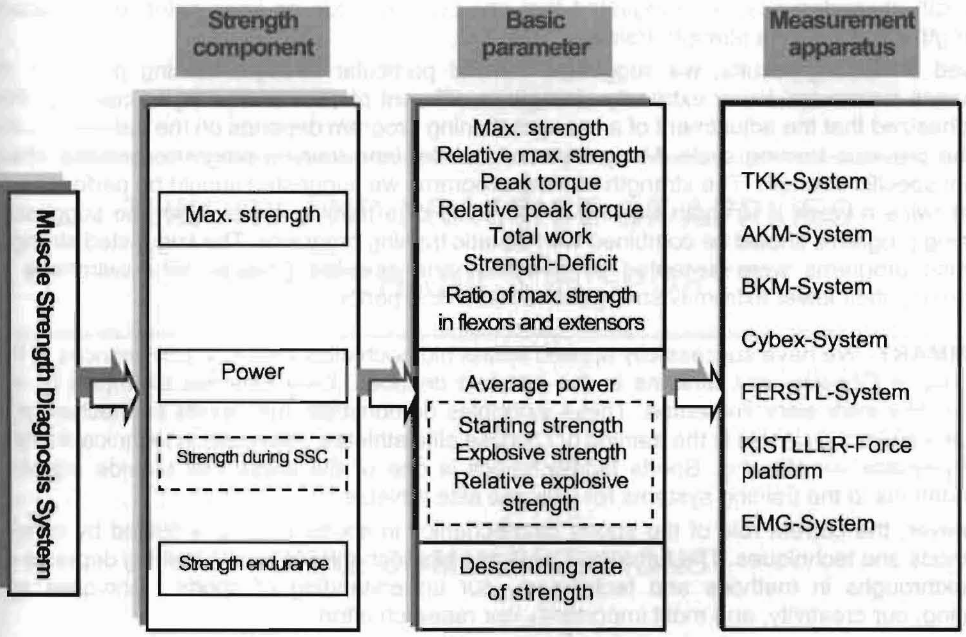

Figure 3 The strength analysis system

Ten elite male swimmers and seven elite female swimmers in the Chinese Swimming Team participated in the study as the subjects. A TKK strength testing machine was used to measure individual joint strengths, while a BKM strength testing machine was used to measure the strength of entire lower extremity. We tested left and right knee extension strength and power for each subject with knee at the 90 degree flexion, and three repetitions for each knee. The subjects were asked to explosively apply force on the strength testing machine, that is to develop maximum strength during the shortest time period. The maximum strength (N), starting strength (N), explosive strength (N/ms), and relative explosive strength (1/ms) were collected for each subject.

The data collected using the BKM strength testing machine reflect the coordination of the hip and knee extensor muscles. Comparison of strength data collected using the TKK and BKM strength testing machines between subjects could show if a given subject's hip extensor strength level was significantly higher than his or her knee extensor strength level, or vice versa. This information would indicate specific weaknesses in the strength of a given subject.

The results of this study show individual lower extremity strength characteristics among subjects. For example, Chengji Jiang, China, men's 50 m freestyle recorder holder, had low lower extremity explosive strength and maximum strength in comparison to other Chinese male swimmers. A swimmer's starting and turning speeds are affected by maximum strength, explosive strength, and starting strength. Which of these three strength components is the determinant of the power depends on the time in which the muscle force applied against resist is developed. Studies by Schmidtbleicher (1984, 1992) have shown that maximum strength is the determinant of power if the time in which the muscle force applied against resist is developed is greater than 150 ms, and that the starting strength and the explosive strength are the determinants of power if the time in which the muscle force applied against resist is developed is less than 150 ms. The times in which swimmers apply forces to the starting block, and the wall of swimming pool are longer than 500 ms. We, therefore, believed that Chengji Jian should focus on training for maximum lower extremity strength.

Hui Qi, the fourth place in women's 200 m breaststroke of 2000 Olympic Games, is another example. Hui Qi had good maximum lower extremity extension strength and greater hip extensor strength compared to knee extensor strength. Based on Hui Qi's lower extremity strength characteristics, we suggested that she put the focus on knee extensor maximum strength and explosive strength training.

Based on testing results, we suggested several particular strength training programs to enhance swimmers' lower extremity strength in different phases of training to coaches. We emphasized that the adjustment of a strength training program depends on the training results of the previous training cycle. Many aquatic, and dry land training programs actually affect event specific strength. The strength training programs we suggested should be performed at least twice a week if strength training is the focus of a training cycle. Also, the suggested training programs should be combined with aquatic training programs. The suggested strength training programs were accepted by coaches, and assisted Chinese elite swimmers in improving their lower extremity strength and swimming performances.

SUMMARY: We have successfully applied sports biomechanics research and services in the training of Chinese elite athletes in the last two decades. Only selected examples of our successful work were presented. These examples demonstrate that sports biomechanics is playing an important role in the training of Chinese elite athletes, especially in technical training and physical conditioning. Sports biomechanics is one of the areas that provide scientific foundations to the training systems for Chinese elite athletes.

However, the current role of the sports biomechanics in sports training is limited by current methods and techniques. The future role of sports biomechanics in sports training depends on breakthroughs in methods and techniques, our understanding of sports techniques and training, our creativity, and most importantly our research effort.

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