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1. SCIENTIFIC BACKGROUND AND OBJECTIVES

1.1 Scientific Background

Male weightlifting is a sport with long history dating back to being included in the first Olympic Games in 1896. This sport is based on dynamic strength and power, in which two different movements (Snatch and Clean & Jerk) are performed sequentially. The final rank is determined on the total result of the heaviest successful lifts of the two movements. In weightlifting, athletes use their reasonable technique, physical, functional and psychological traits to lift a barbell of maximal weight. Of all weight classes in Olympic weightlifting, only the 69-kg is the category common to both genders. The 69-kg class, which is identified as the category with the greatest depth of lifters from top to bottom is representative of national caliber performance in snatch. In the past four Olympic Games (2004, 2008, 2012, and 2016) Chinese male athletes have won the gold medals in the 69-kg class which provides an adequate ground for our investigation.

The technique of top-elite athletes represents the best performance, and can be considered as excellent technical model or a reference that should be achieved. Previous studies of snatch performance focused mainly on the differences in adult female weightlifters, between adult and adolescent males, and between genders. They analyzed the kinematic and kinetic parameters by two or three-dimensional methods. However, the lack of data regarding the stability of snatch technique raises questions regarding the appropriateness of using the specific assistant exercises for improving the success of the snatch lift. Furthermore, no study was found within the literature that compared the snatch performances between top-elite and sub-elite male weightlifters in 69-kg category.

The technical principle of the snatch shows that weightlifters need to follow the three principles of “Near”, “Fast” and “Low” during the snatch process. “Near” means that the barbell is required to be as close to the body as possible during the lifting. “Fast” means that pulling the barbell and action force should be fast. “Low” refers to requiring lifters to reduce the *COG* of body at the fastest speed to facilitate the support to the barbell. With the application of 3-D technology, the parameters which were used to determine the three principles are more diverse and precise. The maximum height of the barbell and the fall distance of the barbell are the key parameters to evaluate the support completion phase. The trajectory of center of gravity (*COG*) of barbell and body are used as an overall analysis of snatch technical characteristics. Spatial-temporal characteristics of barbell, angle of knee, hip, ankle joints are parameters for evaluating the structure of the snatch after the division of snatch movement. Phases of snatch reveal that the snatch technique must not only conform to the mechanics principle, but also adapt to the body structure and physiological characteristics. “Phases” of snatch is an important supplement to the three principles.

Previous study reported that the failed snatch of most elite lifters occurred during the support completion phase. Therefore, it is speculated that the main reason for failure of forward or backward is that the relative position of the *COG* of barbell and body on the sagittal plan exceeds the lifters’ control limit. Since the trajectory of the *COG* of barbell will be different of every attempt of each lifter, and there is a certain relationship between the trajectories of the *COG* of barbell and *COG* of

body, Therefore, it is difficult to find the difference between successful and unsuccessful attempts only from the trajectories of the *COG* of barbell and body. In this case, the human & bar combination barycenter may be a good choice. The concept of human & bar combination barycenter was first coined in 1984. However, due to the technical limitations, the characteristics and the roles of human & bar combination barycenter were not explained in the research at that time.

Patellar tendinopathy is a common overuse injury of the patellar tendon causing pain at the inferior pole of the patella. Prolonged repetitive stress of the knee-extensor apparatus, as in jumping, landing, running, and cutting activities, can lead to this tendinopathy in different sports. The overall prevalence of patellar tendinopathy is high in sports characterized by high demands on speed and power for leg extensors. Because of its chronicity, patellar tendinopathy has substantial impact on the career of many athletes and for some, it is the reason to end their career prematurely.

There is no consensus on what is the most beneficial treatment strategy for patellar tendinopathy based on the current literatures. Extracorporeal shockwave therapy (ESWT) can play a role in the management of tendon pain and should be incorporated into a more comprehensive training rehabilitation plan. Nowadays, ESWT has gained popularity in physiotherapists and clinicians with varying reports of positive effects for patellar tendinopathy.

With the development of ultrasound technology, high-frequency ultrasound has a higher resolution for observing soft tissue and can measure subtle variations in diseased tissues. Recently, ultrasonographic evaluation is widely used for musculoskeletal disorders to assist diagnosis and guide therapy. Ultrasonography is commonly accepted as a method to visualize patellar tendon structure based on its lower cost, availability, and direct clinical correlation. Furthermore, the ultrasonographic changes of patellar tendon tissues can be considered as essential evidence for assessing the effectiveness of ESWT for patellar tendinopathy that should be investigated.

1.2 Scientific Objectives

In my thesis, based on the existing literatures and work needs, I would like to draw up three questions that that are not yet clear or need to be solved urgently.

The 1st research question:

The technique of top-elite athletes represents the best performance, and can be considered as excellent technical model or a reference that should be achieved. Previous studies of snatch performance focused mainly on the differences in adult female weightlifters, between adult and adolescent males, and between genders. However, the lack of data regarding the stability of snatch technique raises questions regarding the appropriateness of using the specific assistant exercises for improving the success of the snatch lift. Furthermore, no study was found within the literature that compared the snatch performances between top-elite and sub-elite male weightlifters.

Therefore, my 1st objective is:

To highlight the differences of technical characteristics between top-elite and sub-elite male weightlifters, to summarize the technical features of top-elite athletes, and to provide valuable information for numerous lower level lifters and coaches to integrate into training and competition.

The 2nd research question:

In the snatch competition, each athlete only has 3 attempts to lift the barbell, so the success rate is the guarantee for the best results. The failed snatch attempts of elite lifters often occurred during the support completion phase, therefore, it is speculated that the main reason for failure of forward or backward is that the relative position of the *COG* of barbell and body on the sagittal plan exceeds the lifters' control limit. Since the trajectory of the *COG* of barbell will be different of every attempt of each lifter, and there is a certain relationship between the trajectories of the *COG* of barbell and *COG* of body, the present study proposes to use the human & bar combination barycenter as the research parameter to find the reason of failed attempts.

Therefore, my 2nd objective is:

To analyzed the three principles of "Near", "Fast", "Low", the phased principle, and the human & bar combination barycenter, to exposit the differences between successful and unsuccessful characteristics of snatch attempts in competition, and to explore the biomechanical factors that cause the snatch failure.

The 3rd research question:

Injury is an important factor that plagues athletes' careers. Patella tendinopathy is currently widespread in my athletes, seriously affecting training and competition. There is no consensus on what is the most beneficial treatment strategy for patellar tendinopathy based on the current literatures. Conservative treatments have been recommended as the initial treatments of option for chronic patellar tendinopathy, but the results of many conservative treatments were irregular and inconsistent, and the symptoms frequently recurred. Numerous studies to evaluate the effectiveness of ESWT for patellar tendinopathy in patients who had not responded successfully to conservative treatments. However, the conclusion of most studies is that ESWT was positively contributed to the improvement of pain symptomatology and function. High-frequency ultrasound has a higher resolution for observing soft tissue and can measure subtle variations in diseased tissues. The ultrasonographic changes of patellar tendon tissues can be considered as essential evidence for assessing the effectiveness of ESWT for patellar tendinopathy that should be investigated.

Therefore, my 3rd objective is:

To observe the ultrasonic image changes of ESWT for patellar tendinopathy from the aspect of repairing the patellar tendon tissues, to study the mechanism of ESWT for patellar tendinopathy based on morphosis, and to discuss the value of musculoskeletal ultrasound in assessing the effectiveness of ESWT for patellar tendinopathy.

2. METHODS

In the analysis of snatch, the data were collected from the Chinese National Championship and the Chinese Olympic Trials. The top six place getters at the Olympic were considered to be top-elite athletes. These six athletes were members of the Chinese National Weightlifting Team. Between them, they had won three Olympic Games gold medals, two World Championships gold medals, and one Asian Games gold medal. Athletes ranked from second to seventh at the Chinese Championships (second-tier weightlifting event in China) were considered to be sub-elite athletes. The lifter who won the gold medal was eliminated because he was included within the top-elite group. The heaviest successful snatch lifts from three attempts for each subject were chosen for comparing between top-elite and sub-elite. The technical performances of top-elite lifters' maximum weights for successful and unsuccessful were selected for analysis. The selection criteria for the unsuccessful performances are that the moment of failure must occur in the support completion phase, and all the unsuccessful performances are forward falling to facilitate the data analysis.

In ESWT for patella tendinopathy, 46 patients with 52 injured knees were initially assessed for eligibility and enrolled in this part. Patients were allocated randomly to a study group or a control group by an independent statistician who was blinded for characteristics of patients. During the treatments, 3 patients with 4 knees were lost to follow-up and excluded from the study. The study group consisted of 22 patients with 25 knees and the control group 21 patients with 23 knees. All patients in this study were active professional athletes.

In order to determine the kinematic parameters of the barbell and body, video and a computerized technique were employed. Two cameras (SONY HDR-FX1000 at 50 Hz) were set up in the horizontal plane, approximately 10 meters away from the subjects. The optical axis of each camera formed an angle of 45 degrees with the frontal plane of the subject. The position and focal length of the cameras remained unchanged during the whole process of snatch lift. The methodology of our research focused on video recording, conversion of video capture into AVI format and the kinematic variables which were analyzed by SIMI°Motion7.50 3D analysis system (Germany). Before the start of the competition, a PEAK 3D framework was used to calibrate the movement space. The spatial coordinates of various points were calculated from the collected video by means of direct linear transformation (DLT) method. The raw position-time data were smoothed by a low-pass digital filter with a cut-off frequency of 4 Hz.

The snatch process (from start position to squat position) was divided into six phases (abbreviated as *M1-M6*) based on the changes in direction of the knee angle, the vertical velocity of barbell, and the vertical height of barbell. In the process of video digitization, seventeen key points on the barbell and the body were selected. These points included the head, left and right shoulders, left and right elbows, left and right wrists, left and right hips, left and right knees, left and right ankle bones, left and right tiptoes, left and right endpoints of barbell. *COG* position of body was calculated using Hanavan Body Mathematical Model. *COG* position of the barbell was obtained by calculating the geometric center from the coordinates of the two endpoints. The position of Human & bar combination barycenter was calculated by the *COG* of combined objects in physics.

Chronic patellar tendinopathy is defined as recurrent pain and tenderness due to degenerative changes of patellar tendon for at least 6 months. This part is a randomized controlled trial with blinded participants and outcomes assessors, using two-group repeated measures design. In Study group, physical therapists explained the treatment procedure to patients and palpated the patellar tendon to find the most painful spot. ESWT was applied according to the operating instruction of the shockwave device (EMS Swiss Dolorclast Cart, Switzerland). Patients were in supine position with a slightly extended knee. All patients in the study group received 3 radial ESWT treatments without local anaesthesia at 1-week interval. Each session consists of 2000 impulses at 10 Hz. 500 impulses were performed around the point of maxima tenderness at a treatment intensity of 2 bar. Then the applicator was moved to the point of maxima tenderness, 500 impulses were given at intensity of 2, 2.5 and 3 bar respectively. 15 mm diameter applicator was selected. Transmission gel was applied between the applicator and the skin. Patients were allowed to resume light activities, however, heavy activities were not permitted for 6 months. In control group, all patients were treated with rest intervention only. They were also allowed to resume light activities, however, heavy activities were not permitted for 6 months.

Follow-up measurements were carried out at before, 3 and 6 months after the final ESWT treatment. The patellar tendon was imaged by an experienced musculoskeletal sonographer using a Philips ATL 5000 ultrasound machine with a 13MHz linear probe (Philips Medical Systems, Bothell, Washington). The longitudinal length of the whole patellar tendon was measured on sagittal image. The thickness of proximal and distal part of patellar tendon were measured on axial image. The proximal part was defined as the area where the patellar tendon attaches to the inferior pole of the patella, and the distal part as the area where it attaches to the tibial tuberosity. The data of hypo-echogenic and Calcifications zones were also measured.

3. NEW RESULTS, THESIS

My thesis contains three parts, the topics are "**Differences in key techniques of snatch**

between top-elite and sub-elite lifters", "**Failed snatch based on the human & bar combination barycenter**", and "**Ultrasonic image changes of extracorporeal shockwave therapy for patellar tendinopathy**" respectively. The thesis points as follow:

The part 1 thesis points: I experimentally identified that *M1-M3* phases will enhance the snatch technique and will make a significant difference between top-elite and sub-elite weightlifters. With regard to lower limb movement pattern, I recognized that the knee joint angle (*KA*) has the most significant effect on the snatch technique. Because the barbell rising mainly relies on the knee extension in the first three phases, and the barbell height is the guarantee for snatch. Therefore, the strength of the lower limb is particularly important, and the ability to extend knee joint is the specific manifestation. Therefore, we can conclude that sub-elite lifters must develop their knee extension capability, similarly to top-elite lifters, to reach higher efficiency.

I experimentally determined that the angular velocity of the knee joint (*KAV*) during *M2* has also a particular effect on efficiency. We can state that a higher angular velocity must be carried during *M2* in order to achieve the best performance if sub-elite and top-elite lifters are compared. Because the flexion of the knee joint during *M2* should rapidly enough to store recoverable elastic energy and to elicit stretch reflex immediately, which is beneficial to the force generation in M3. Just like the rapid squat before the jump in the vertical jump.

Related articles to part 1 thesis points:

[1] **Liu Gongju**, Gusztáv Fekete, Hongchun Yang, Jing Ma, Dong Sun, Qichang Mei, Yaodong Gu, (2018). Comparative 3-dimensional kinematic analysis of snatch technique between top-elite and sub-elite male weightlifters in 69-kg category. *Heliyon*, 4(7), e00658.

[2] **Liu Gongju**, Li Jianshe, Pan Huiju, (2019).Critical technique characteristics of snatch at nearly extreme mass of Olympic champions. *Journal of Beijing Sport University*, 42(9), 127-136.

[3] **Liu Gongju**, Bi Zhiyuan, Hu ting, (2015). Speed indicators analysis on the snatch in Chinese Male's small levels (56 to 77 kg class) weightlifting athletes. *Zhejiang Sport Science*, 37(5), 125-128.

The part 2 thesis points: The three principle parameters ("Near", "Fast" and "Low") and its supplementary principle ("Phases") cannot effectively analyze the difference between successful and failed snatch technique. Based on the "combination barycenter" of combined objects in physics, for the first time in my thesis, the human & bar combination barycenter was used in practice and to judge the difference between the successful and failed snatch technique.

I concluded that the key factor of failed snatch is the insufficient increase of human & bar combination barycenter on the *X*-axis during the *M*4 and *M*5 phases. If weightlifters can ensure the sufficient increase range of human & bar combination barycenter on the *X*-axis during *M*4-*M*5, then the success rate of snatch can be improved. Because, the values of success is significantly greater than that of failure, combined with the form of snatch action, we can concluded that the direct cause of failed snatch is the position of the human & bar combination barycenter on the *X*-axis is more forward at the end of *M5*.

Related articles to part 2 thesis points:

[1] Sun Xiaoyu, Pan Huiju, **Liu Gongju**, Zheng Zhe, (2020). A study on the causes of snatch failure based on the relationship between body-barbell resultant gravity center and bearing surface center. *Zhejiang Sport Science*, 42(2), 107-112.

[2] Zhu Houwei, Shi Shusheng, Shen Cuimei, **Liu Gongju**, Pan Huiju, (2019). A biomechanical study on the failure of snatch in high-level athletes based on the human & bar combination barycenter. *China Sport Science and Technology*, 55(9)39-46.

The part 3 thesis points: Patella tendinopathy is currently widespread in my athletes, and it is one of the important factors hindering the improvement of athletes' performance, which seriously affecting training and competition. In my thesis, I experimentally determined on professional, active athletes that Extracorporeal Shockwave Therapy (ESWT), combined with rest, can effectively improve the morphology of patella tendon, since the five main properties (proximal-, distal thickness, longitudinal length, hypo-echogenic, and calcifications zones) were significantly reduced. Due to this applied therapy, more than 90% of the athletes who participated in the study could return to their professional sport carrier. Therefore, ESWT combined with rest can effectively treat patella tendinopathy, and musculoskeletal ultrasound can accurately monitor the treatment effect. Due to this applied therapy, more than 90% of the athletes who participated in my study not only could return to their professional sport carrier, but also many of them achieved excellent results.

Related articles to part 3 thesis points:

Liu Gongju, Jing Ma, Yichao Ji, Hongchun Yang, Gusztáv Fekete, (2019). Ultrasonic image changes of extracorporeal shockwave therapy for patellar tendinopathy in Chinese professional athletes. *Journal of Medical Imaging and Health Informatics*, 9(3), 566-572.

4. SCIENTIFIC PUBLICATIONS

4.1 Referred articles related to this thesis:

1. **Liu Gongju**, Gusztáv Fekete, Hongchun Yang, Jing Ma, Dong Sun, Qichang Mei, Yaodong Gu, (2018). Comparative 3-dimensional kinematic analysis of snatch technique between top-elite and sub-elite male weightlifters in 69-kg category. *Heliyon*, 4(7), e00658, **Q1**

2. **Liu Gongju**, Jing Ma, Yichao Ji, Hongchun Yang, Gusztáv Fekete, (2019). Ultrasonic image changes of extracorporeal shockwave therapy for patellar tendinopathy in Chinese professional athletes. *Journal of Medical Imaging and Health Informatics*, 9(3), 566-572. **IF: 0.499, Q4**
3. **Liu Gongju**, Li Jianshe, Pan Huiju, (2019). Critical technique characteristics of snatch at nearly extreme mass of Olympic champions. *Journal of Beijing Sport University*, 42(9), 127-136.
4. **Liu Gongju**, Bi Zhiyuan, Hu ting, (2015). Speed indicators analysis on the snatch in Chinese Male's small levels (56 to 77 kg class) weightlifting athletes. *Zhejiang Sport Science*, 37(5), 125-128.
5. Sun Xiaoyu, Pan Huiju, **Liu Gongju**, Zheng Zhe, (2020). A study on the causes of snatch failure based on the relationship between body-barbell resultant gravity center and bearing surface center. *Zhejiang Sport Science*, 42(2), 107-112.
6. Zhu Houwei, Shi Shusheng, Shen Cuimei, **Liu Gongju**, Pan Huiju, (2019). A biomechanical study on the failure of snatch in high-level athletes based on the human & bar combination barycenter. *China Sport Science and Technology*, 55(9)39-46.
7. Bi Zhiyuan, Zhao Yan, **Liu Gongju**, Zhang Long, (2018). Kinematic analysis of the snatch technique of the Rio Olympic champion Shi Zhiyong. *Sichuan Sport Science*, 37(3), 73-76.
8. Chang Pengfei, Liu Jin, Zhu Houwei, **Liu Gongju**, Pan Huiju, (2018). A study on the snatch techniques of Lü Xiaojun in trials for the Rio Olympic Games. *Journal of Zhejiang Normal University (Nat. Sci.)*, 41(1), 115-120.

4.2 International conference publications related to this thesis:

1. **Liu Gongju**. Traction behavior of soccer shoe stud designs under different game-relevant loading conditions. *International Science and Football Conference (ISAFA) 2017*. At: Ningbo, China.
2. **Liu Gongju**, Gusztáv Fekete, Yaodong Gu. The kinematic analysis on barbell's horizontal displacement of Chinese elite weightlifting athletes. *Asian Society of Sports Biomechanics Conference (ASSB) 2016*. At: Ningbo, China.
3. Kangwei Ai, Zhiyuan Bi, **Liu Gongju**, (2018). Bar heights needed for successful lifts in men's weightlifters. *International Society of Biomechanics in Sports (ISBS)*. 36(1), 899-902. At: Auckland, New Zealand.
4. **Liu Gongju**, Ying Chunyi, Ma Jing, Hu Ting. Critical technique characteristics of snatch at nearly extreme mass of Olympic champions. *Chinese Association of Biomechanics in Sports (CSSB) 2018*. At Lanzhou, China.
5. Zhu Houwei, Shen Cuimei, Shi Shusheng, **Liu Gongju**, Pan Huiju. Biomechanical study on the failure of snatch in high-level athletes based on the human & bar combination barycenter. *China Sport Science Society (CSSS) 2019*. At: Nanjing, China.
6. Ying Chunyi, **Liu Gongju**, Ma Jing, Pan Huiju. Study on the effect of "warm-up" for the Functional Movement Screen in predicting sport injury risk. *Chinese Association of Biomechanics in Sports (CSSB) 2018*. At Lanzhou, China.

4.3 Scientific research projects related to this thesis:

1. **Liu Gongju**, Zhu Houwei, Hu Ting, Bi Zhiyuan, et al., (2020). Technology support service on the key weightlifting techniques of Shi Zhiyong prepares for Olympic Games. From: General Administration of Sport of China.
2. **Liu Gongju**, Hu Ting, Xu Lü, Bi Zhiyuan, et al., (2020). Comparative study on snatch technique between top-elite and sub-elite male weightlifters in 69-kg category in China. From: Sport Bureau of Zhejiang Province.
3. **Liu Gongju**, Ma Jing, Bi Zhiyuan, Wang Guangwei, et al., (2017). Research and application of key techniques of major male weightlifters in 69kg and 77kg categories of Zhejiang province. From: Sport Bureau of Zhejiang Province.
4. **Liu Gongju**, (2016). Research on optimization of key technical parameters for snatch major weightlifters of National Weightlifting Team in 2016 Olympic Games. From: Education Office of Zhejiang Province.
5. Guo Haiying, Chen Qian, Geng Weidong, **Liu Gongju**, et al., (2020). Research and development of AI-based motion recognition and sports assistance system-the key technology optimization and training assistance system for Zhejiang athletes preparing for the Hangzhou Asian Games. From: Zhejiang Provincial Department of Science and Technology.

4.4 Other publications:

1. **Liu Gongju**, Yu Jinxing, Hu Ting, Ying Chunyi, Pan Huiju, (2019). Study on the effect of "warm-up" for the Functional Movement Screen™ (FMS™) in predicting sport injury risk. *Zhejiang Sport Science*, 41(2), 92-97.
2. **Liu Gongju**, Fang Haibo, Hu ting, Ying Chunyi, (2014). The optimization analysis on Chinese excellent women's double kayak sprint. *Zhejiang Sport Science*, 36(5), 105-108.
3. Liu Yuwei, Chen Feifei, **Liu Gongju**, Liang Zhiqiang, Popik Sergey, Lian Wenlan, (2020). Moxibustion intervention effect to vertical jump performance. *Journal of Medical Imaging and Health Informatics*, 10(5), 1171-1177. **IF: 0.499, Q4**
4. Wenjing Quan, Meizi Wang, **Liu Gongju**, Gusztáv Fekete, Julien S Baker, Feng Ren, Yaodong Gu, (2020). Comparative analysis of lower limb kinematics between the initial and terminal phase of 5km treadmill running. *Journal of Visualized Experiments*, **IF: 1.300, Q3**
5. Fekete, G., Sun, D., **Liu Gongju**, Gu, Y. D., Balassa, G. P., Bíró, I., ... & Jánosi, E. (2018). Preliminary Results of Size and Slide-Roll Effect on the Kinematics of Total Knee Replacements. *Acta Polytechnica Hungarica*, 15(6), 143-153. **IF: 1.286, Q3**
6. Wu Ziying, Li Jianshe, **Liu Gongju**, Ying Shanshan, Shao Guoqiang, (2021), Biomechanical analysis of key points in typical techniques of squat clean and jerk of Li Dayin and Lyu Xiaojun. *China Sport Science and Technology*, 57(1), 58-65.
7. Dan Linfei, Wu Ziying, Shi Zhiyong, Mei Qichang, **Liu Gongju**, Li Jianshe, (2021), The kinematics analysis of the key technique of the classic women's split jerk-Based on the technical

diagnosis of Liao Qiuyun's breaking the world record in clean and jerk at the World Championship. *Zhejiang Sport Science*, 43(2), 96-103.

8. Ma Jing, Gong Zaifeng, Li Hang, **Liu Gongju**, (2021). Analysis of the characteristics of biochemical indexes of Zhejiang youth men's volleyball athletes before key games. *Zhejiang Sport Science*, 43(1), 95-100.
9. Ma Jing, **Liu Gongju**, (2020). Application of surface electromyography combined with isokinetic in the research of sEMG-force relationship of knee. *Zhejiang Sport Science*, 42(3), 64-68.
10. Pan Xu, Zheng Zhe, **Liu Gongju**, Pan Huiju, (2019). Influence of women pole vaulting index in each stage to sport performance. *Zhejiang Sport Science*, 41(6), 102-108.
11. Jiang Kai, Pan Huiju, **Liu Gongju**, (2018). Kinematic analysis of the jerk technique of Lü Xiaojun Olympic weightlifting champion. *Journal of Zhejiang Normal University (Nat. Sci.)*, 41(4), 474-480.
12. Ma Jing, **Liu Gongju**, Wang Jian, (2018). Research and Prospect of Array Surface EMG characteristics of muscle fatigue. *Chinese Journal of Physical Medicine and Rehabilitation*, 40(4), 318-320.
13. Ma Jing, **Liu Gongju**, (2016). Application of data miming technology in volleyball athletes' biochemical indexes analysis. *Zhejiang Sport Science*, 38(5), 96-99.
14. Ma Jing, **Liu Gongju**, Wang Jian, (2015). The differences in muscles activity under the different gait speeds between hemiplegic and healthy lower extremity. *Chinese Journal of Sports Medicine*, 34(9), 850-853.
15. Ying Chunyi, **Liu Gongju**, (2015). The speed control model research of short distance 200 meters sprint canoeing. *Zhejiang Sport Science*, 37(1), 117-121.