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# EMG Analysis of Volleyball Athletes in the Process of Blocking at Different Knee Take-off Angles

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***Abstract:*** *The knee joint is a primary mobile joint in the lower limbs, contributing the most to the height of take-off and is an important factor affecting take-off effect. Analyzing the muscle force and movement characteristics of the knee joint in athletes provides a reference for sports training and injury prevention. Through experimental methods, the study on the EMG of volleyball athletes' lower limbs during blocking showed significant differences in the impact of deep squat and shallow squat on the tibialis anterior muscle during squatting (p=0.027‹05); significant differences in the impact of deep squat and shallow squat on the tibialis anterior muscle during the landing phase (p=0.017); significant differences in the impact of deep squat and half squat on the tibialis anterior muscle (p=0.001‹05) as well as on the rectus femoris (p=0.015‹05) in the pedal-stretch phase; and significant differences in the impact of deep squat and shallow squat on the rectus femoris during the aerial phase (p=0.019). Since the rectus femoris is the primary knee-extension muscle and plays a role in buffer and immobilization, it determines the height of take-off to a certain extent. To effectively improve jump height, the force training of the rectus femoris should be enhanced, which can also help prevent sports-related injuries. The rectus femoris is a major muscle for maintaining body balance, and the medial head of gastrocnemius muscle and the lateral head of gastrocnemius muscle play critical roles in maintaining balance in the air. It is necessary to strengthen the coordinated training among these muscles to boost their work efficiency.*

***Keywords:*** *Volleyball; Take-off; Blocking; EMG; Knee Joint*

## 1. Introduction

In the study of volleyball, the application of interdisciplinary knowledge such as big data, modeling, training science, management, physiology, biochemistry, psychology, and biomechanics is extensive. Many research findings focus on the study on the EMG of upper limbs, waist, and abdominal muscles, as well as the assessment of physiological and biochemical indexes and the improvement of training methods. However, there is limited research on the changes in the EMG of lower limbs during blocking at different take-off angles. As volleyball techniques and tactics continue to mature, and due to the rapid attack and defense transitions during intense matches, and the impact of the system of scoring a point per goal, it is crucial to strengthen the research on the EMG of lower limbs during blocking to enable athletes to better utilize the force of their lower limbs and to improve the effect of spiking or blocking.

## 2. Experimental Process

Synchronous testing was conducted with an 8-channel portable electromyograph produced in Finland, along with a camera (Sony high-speed camera). Specifically, the portable electromyograph was fixed on the lower back of the athlete, with channels 1 to 6 connected to electrodes attached to six muscles on the right lower limb, and channel 8 connected to the signal receiver. Besides, the signal receiver was fixed on the camera, and an infrared diode was placed within the shooting range to facilitate synchronization effect between the camera and the electromyograph.

### *2.1 Experimental Apparatuses*

During the experiment, a Finland-made MegaWin 6000 surface electromyograph and related analysis software were used.

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### *2.2 Test Indexes*

According to the needs of this experimental study, as the take-off was done in situ for blocking, the synchronous test focused on six muscles on the right lower limb: gluteus maximus, biceps femoris muscle, rectus femoris, lateral head of gastrocnemius muscle and tibialis anterior muscle. Integrated EMG values and muscle discharge timing data were obtained in the end.

### *2.3 Test Methods*

Take off in situ for blocking. Facing the 2.43-meter-high net, lift your hands close to the net on the chest. When taking off, the arms will swing back and forth in unison. Only after grasping the movement can the test be performed. Select three angle ranges in normal squat (half squat): 60°-90°, 90°-120°, 120°-150°, and the angle range of blocking take-off that one is used to. Take off 3 times in each angle range and take off as hard as possible. There is a 10-second interval between every two take-offs, and each take-off takes place after hearing the slogan of the tester. When testing, measure your own habitual angle first, and the other three angle ranges are tested in turn from small to large, with a 5-minute rest between every two angle ranges.

### *2.4 Mathematical Statistics*

Copy the data to the software EXCEL2007 for analysis and processing, conduct further analysis and processing with SPSS13.0 statistical software, make a statistical description of the mean value and standard deviation of each index, and make a one-way ANOVA for the phenomena caused by different angles.

## 3. Working Process and Selection of Test Indexes

### *3.1 Division of Time Phases during Blocking*

To meet the needs of the research purpose, this study only analyzes the three links of take-off, aerial and landing. Since this paper studies the movement of the lower limbs for blocking by taking off in situ, and the unified movement of upper limbs is not involved in the analysis, the take-off link starts with the movement of joint points and ends with the moment when both feet leave the ground, and this process is the take-off link. To analyze the kinematics in a more convenient, reasonable, objective and effective way, this paper divides the take-off link into two phases: buffer and pedal-stretch for research and analysis, based on the anatomical conditions such as the working form of muscles for the take-off movement of volleyball blocking.

• Buffer phase: In this study, the experiment begins when the athletes are in the upright position, starting from the knee joint point and ending at the lowest point when the speed is zero and the angle is the smallest. This process is referred to as the buffer phase of take-off.

• Pedal-stretch phase: It starts at the moment when the knee and hip joint reach the lowest point during the descent, and ends at the moment when the feet leave the ground. This process is referred to as pedal-stretch phase of take-off.

• Aerial phase: It starts with the end time of the take-off phase (that is, the moment when the feet leave the ground) and ends with the moment when the feet fall to the ground (the feet touch the ground). This process is referred to as the aerial phase.

• Landing phase: It the process from the moment when the foot touches the ground to the moment when the knee and hip are down to the lowest point again (one or both feet are possible).

### *3.2 Selection of EMG Test Indexes*

Commonly used analysis indexes are chosen in the EMG analysis: integrated EMG value and muscle discharge sequence (that is, muscle mobilization sequence).

Hua Lijun and Song Jirui[1] studied the muscle force of lower limbs, EMG characteristics and the relationship between them with integrated EMG values, which provided scientific basis for designing special force training methods and preventing sports-related injuries; besides, the collected EMG signals of quadriceps femoris can help explain the relationship between the integrated EMG and muscle

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force indexes and guide the practice of special force training. This reveals that EMG technology has been well used in volleyball events.

### *3.3 EMG Analysis in Downward Buffer Phase*

As can be seen from Figure 1,as in the process of squatting, the exercise time is rather short, the muscles are working continuously, and the electromyogram is a closely-lined continuous figure, it is not conducive to the overall macro description of the exercise process if the downward buffer phase is divided into the front and rear parts for EMG analysis.

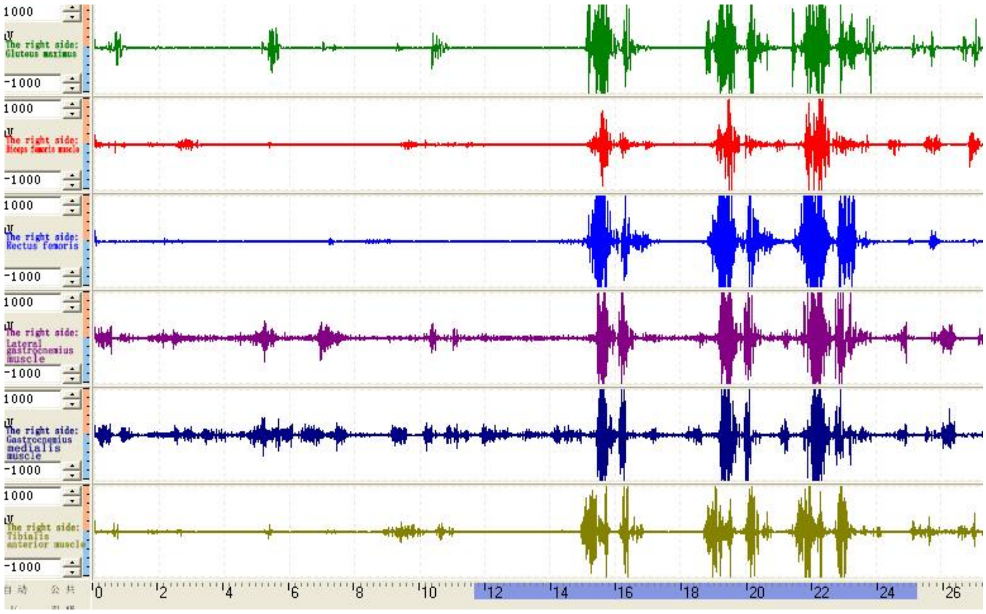

*Figure 1: Original Electromyogram*

## 4. Integrated EMG Value of the Whole Downward Buffer Phase

### *4.1 Integrated EMG Value of the Whole Downward Buffer Phase*

The analysis of the integrated EMG value promotes an indirect understanding of the muscle contribution rate. Analyzing the integrated EMG values of the six muscles chosen in the squat phase can help guide the work done by the muscles in the squat phase.

*Table 1: Integrated EMG Value during Squat Buffer ($\bar{x}\pm s$)     Unit: uvs     n=6*

| | Shallow Squats | Half Squats | Deep Squats |
|---|---|---|---|
| Gluteus Maximus | 23.45±17.22 | 38.72 ±17.64 | 42.86 ±17.67 |
| Biceps Femoris Muscle | 10.58±6.78 | 15.72 ±9.09 | 25.81 ±12.81 |
| Rectus Femoris | 33.57±15.99 | 58.32±22.52 | 70.56 ±23.62 |
| Lateral Head of Gastrocnemius Muscle | 23.97±11.59 | 23.73±14.24 | 34.66 ±17.06 |
| Medial Head of Gastrocnemius Muscle | 36.78±20.75 | 30.89±18.67 | 91.2±37.15 |
| Tibialis Anterior Muscle | 41.63±15.65 | 29.96±15.20 | 126.84±60.21 |

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*Table 2: Statistical analysis of integrated EMG Value during Squat Buffer*

| | | Sum of Squares | df | Mean Square | F | p. |
|---|---|---|---|---|---|---|
| Gluteus Maximus | Between Groups | 9322.004 | 2 | 4661.002 | .631 | .546 |
| | Within Groups | 110852.710 | 15 | 7390.181 | | |
| | Total | 120174.714 | 17 | | | |
| Biceps Femoris Muscle | Between Groups | 720.736 | 2 | 360.368 | 3.695 | .050 |
| | Within Groups | 1463.050 | 15 | 97.537 | | |
| | Total | 2183.785 | 17 | | | |
| Rectus Femoris | Between Groups | 1923.501 | 2 | 961.750 | 1.371 | .284 |
| | Within Groups | 10520.460 | 15 | 701.364 | | |
| | Total | 12443.961 | 17 | | | |
| Lateral Head of Gastrocnemius Muscle | Between Groups | 467.946 | 2 | 233.973 | 1.117 | .353 |
| | Within Groups | 3140.581 | 15 | 209.372 | | |
| | Total | 3608.526 | 17 | | | |
| Medial Head of Gastrocnemius Muscle | Between Groups | 1554.307 | 2 | 777.154 | 1.032 | .380 |
| | Within Groups | 11292.803 | 15 | 752.854 | | |
| | Total | 12847.111 | 17 | | | |
| Tibialis Anterior Muscle | Between Groups | 17764.313 | 2 | 8882.157 | 4.647 | .027 |
| | Within Groups | 28671.822 | 15 | 1911.455 | | |
| | Total | 46436.136 | 17 | | | |

As can be observed from Table 1 and 2 above, it is concluded that $F(2,17) = 4.647$, $P = 0.02705$, which reveals that shallow squat, half squat and deep squat have significant differences on the tibialis anterior muscle. Through back testing (LSD), it is concluded that there are significant differences in the impact of deep squat and shallow squat on the tibialis anterior muscle ($p = 0.027<0.5$). During the buffer phase, the tibialis anterior muscle is the prime mover muscle of foot extension, so it shows significant differences, which reveals that the tibialis anterior muscle is an important muscle that plays a buffer role in the falling process of human body, which is also the reason for the premature fatigue of tibial muscles in daily training.

#### *4.2 Muscle Discharge Sequence in the Whole Downward Buffer Phase*

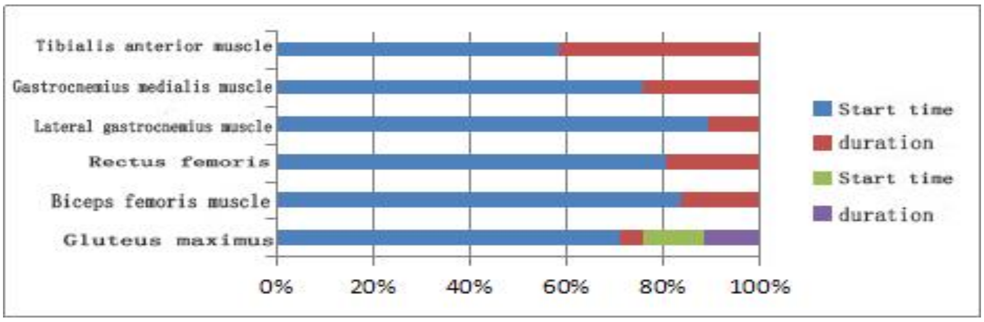


*Figure 2: Muscle Discharge Sequence during Shallow Squat Buffer*

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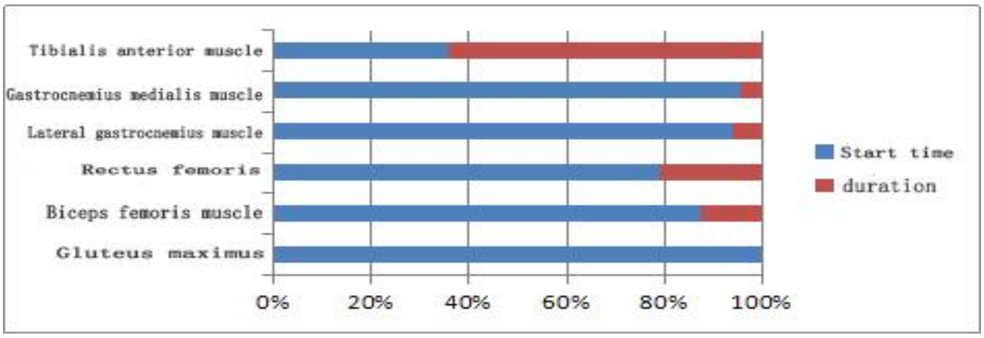


*Figure 3: Muscle Discharge Sequence during Half Squat Buffer*

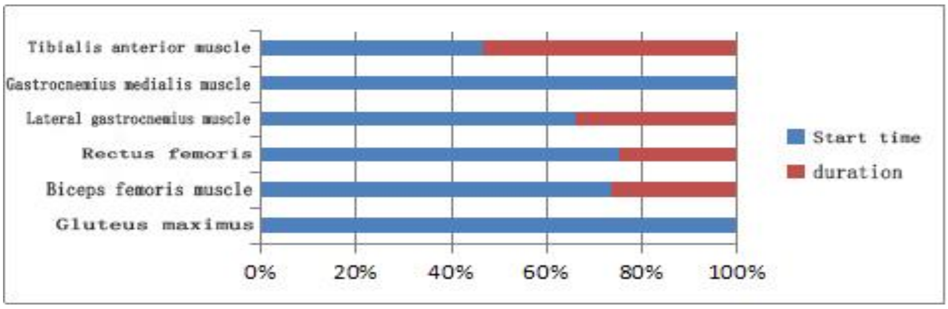


*Figure 4: Muscle Discharge Sequence during Deep Squat Buffer*

As can be seen from Figures 2, 3 and 4,the above three diagrams of muscle mobilization sequence during buffer indicate that the discharge sequence is consistent as a whole, but the difference is chiefly embodied in biceps femoris muscle and gluteus maximus. Since the movement in this phase makes the human body squat by its own gravity, it shows that there is no phenomenon of force exertion in the first half of the discharge sequence, and the force exertion appears in the second half of the buffer phase, chiefly because the immobilization phase is at the back of the buffer phase. During the immobilization process, the force exertion and immobilization of tibialis antenna muscle, gastrocnemius muscle, biceps femoris muscle and rectus femoris to prepare for the pedal-stretch in the follow-up. Gluteus maximus is basically in a relaxed state, and there is no phenomenon of force exertion. The phenomenon of one player's force exertion is chiefly caused by his personal habits or because his body is not coordinated enough. During half squat, gluteus maximus does not exert force, but during shallow squat and deep squat, a few athletes exert force, and the other muscles do not undergo force exertion until the last time, which is due to the muscle force exertion caused by deceleration immobilization in the second half of squat, but these muscles are the main muscles for bending the feet and extending the knee. The tibialis anterior muscle is the first to exert force, and it is the main muscle to stretch the feet.

Wang Fanjia and Zhou Chenlei[2] also hold that during the "Asian squat" where the soles of the feet touch the ground, the activation degree of the tibialis anterior muscle is significantly higher than that of the "Western squat" which requires the human body's center of gravity to move forward.

## 5. EMG Analysis of Pedal-Stretch Phase

Pedal-stretch, as the key link of blocking, directly influences the height of take-off, so it is essential to study the force exertion of lower limb muscles in the pedal-stretch phase.

### *5.1 Integrated EMG Value in Pedal-Stretch Phase*

*Table 3: Integrated EMG Value during Squatting Pedal-Stretch ($\bar{x}\pm s$)      Unit: uvs*

| | Shallow Squats | Half Squats | Deep Squats |
|---|---|---|---|
| Gluteus Maximus | 57.77±45.21 | 72.45±47.09 | 72.06±33.70 |
| Biceps Femoris Muscle | 30.33 ±14.72 | 43.66±23.66 | 66.23±48.89 |
| Rectus Femoris | 60.75±28.56 | 99.60±40.13 | 126.28±32.46 |
| Lateral Head of Gastrocnemius Muscle | 61.70±45.80 | 68.46±27.71 | 97.59±45.41 |
| Medial Head of Gastrocnemius Muscle | 66.64 ±23.72 | 89.15 ±17.31 | 110.42±44.16 |
| Tibialis Anterior Muscle | 16.45 ±7.66 | 31.30±9.88 | 75.25±36.65 |

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*Table 4: Statistical analysis of integrated EMG Value during Squatting Pedal-Stretch*

| | | Sum of Squares | df | Mean Square | F | p. |
|---|---|---|---|---|---|---|
| Gluteus Maximus | Between Groups | 839.609 | 2 | 419.805 | .233 | .795 |
| | Within Groups | 26984.743 | 15 | 1798.983 | | |
| | Total | 27824.352 | 17 | | | |
| Biceps Femoris Muscle | Between Groups | 3951.295 | 2 | 1975.647 | 1.871 | .188 |
| | Within Groups | 15834.792 | 15 | 1055.653 | | |
| | Total | 19786.087 | 17 | | | |
| Rectus Femoris | Between Groups | 13030.408 | 2 | 6515.204 | 5.616 | .015 |
| | Within Groups | 17401.688 | 15 | 1160.113 | | |
| | Total | 30432.096 | 17 | | | |
| Lateral Head of Gastrocnemius Muscle | Between Groups | 4365.709 | 2 | 2182.855 | 1.329 | .294 |
| | Within Groups | 24637.986 | 15 | 1642.532 | | |
| | Total | 29003.696 | 17 | | | |
| Medial Head of Gastrocnemius Muscle | Between Groups | 5750.294 | 2 | 2875.147 | 3.066 | .076 |
| | Within Groups | 14064.881 | 15 | 937.659 | | |
| | Total | 19815.175 | 17 | | | |
| Tibialis Anterior Muscle | Between Groups | 11218.057 | 2 | 5609.029 | 11.220 | .001 |
| | Within Groups | 7498.644 | 15 | 499.910 | | |
| | Total | 18716.701 | 17 | | | |

As can be observed from Table 3 and 4 above,it is concluded that F(2,17)=11.220, p=0.001‹05, which reveals that shallow squat, half squat and deep squat show highly significant differences on the tibialis anterior muscle. Through back testing (LSD), it is concluded that the impact of deep squat and half squat on the tibialis anterior muscle is significantly different (p=0.001‹05), which is chiefly due to the delay of the continuous movement of the tibialis anterior muscle to the pedal-stretch phase during squat immobilization; meanwhile, there are significant differences on the rectus femoris. Through back testing (LSD), it is concluded that there are significant differences in the impact of deep squat and shallow squat on the rectus femoris (p=0.015‹05). Anatomically, it is known that the rectus femoris is the primary motor muscle of knee extension. This is chiefly because the rectus femoris is the main knee-extension muscle in the pedal-stretch process, and it is the prime mover muscle; more importantly, due to the different pedal-stretch distance of deep squat and shallow squat and acting time, the force value represented will be highly obvious. However, there are no differences in other muscles, for the main reason that during this pedal-stretch phase, muscles that bend their feet, extend their knees and are quite wide as prime mover muscles are all exerting their force to help pedal-stretch take off. The tibialis anterior muscle is the antagonistic muscle of feet flexion and the prime mover muscle of knee extension.

### *5.2 Muscle Discharge Sequence in the Pedal-Stretch Phase*

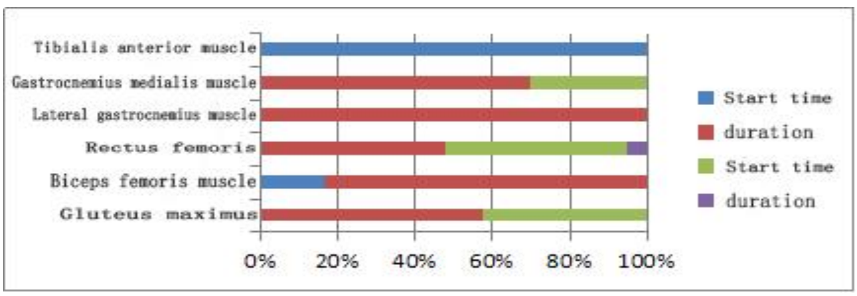


*Figure 5: Muscle Discharge Sequence in the Shallow Squat Pedal-Stretch*

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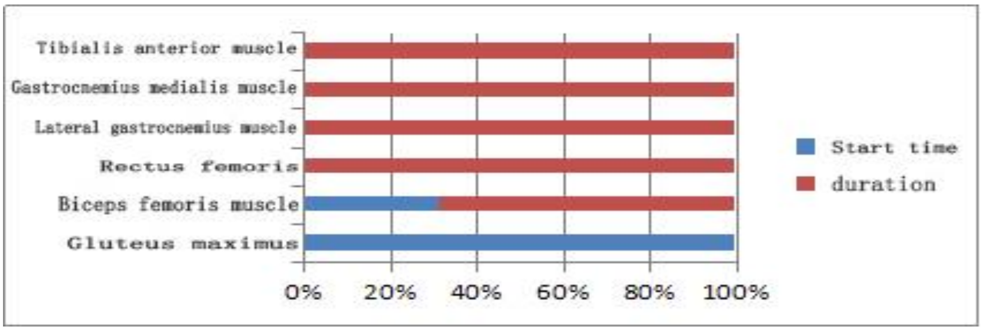


*Figure 6: Muscle Discharge Sequence in the Half Squat Pedal-Stretch*

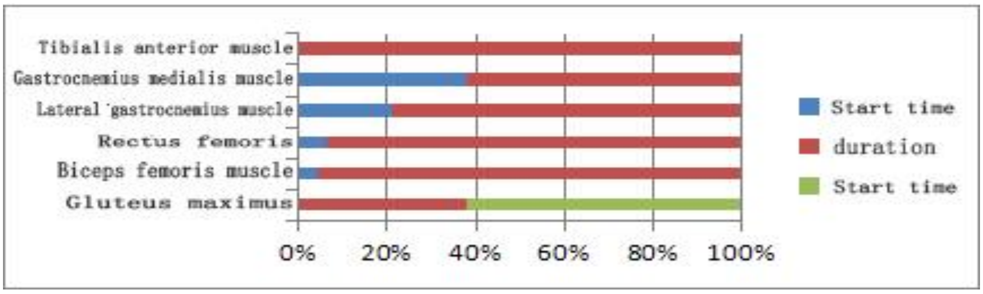


*Figure 7: Muscle Discharge Sequence in the Deep Squat Pedal-Stretch*

As can be seen from Figures 5, 6 and 7,the above three pedal-stretch diagrams clearly show that in the pedal-stretch phase, pedal-stretch muscle as hip and knee joint and prime mover muscle as the flexor of ankle joint are actively exerting force, showing the maximum pedal-stretch force as a whole, but taking off at different angles shows its own characteristics. It can be clearly seen that the rectus femoris is the primary prime mover muscle of knee extension, and the medial and lateral heads of gastrocnemius muscle is the primary prime mover muscle of feet flexion.

Liu Gang [3] pointed out that the primary working muscle in knee-joint extension is rectus femoris, and the EMG signal of rectus femoris does not take on definite change trend along with the increase of motion speed.

## 6. EMG Analysis of the Aerial Process

### *6.1 Integrated EMG Value of the Whole Aerial Process*

*Table 5: Integrated EMG in the Whole Aerial Process ($\bar{x}\pm s$)        n=6*

| | Shallow Squats | Half Squats | Deep Squats |
|---|---|---|---|
| Gluteus Maximus | 54.93±38.43 | 100.72±91.88 | 95.35±43.01 |
| Biceps Femoris Muscle | 26.89±12.72 | 45.96±34.92 | 68.82±32.67 |
| Rectus Femoris | 37.30±13.97 | 60.16±24.95 | 75.39±21.35 |
| Lateral Head of Gastrocnemius Muscle | 59.53±35.34 | 70.63±46.09 | 65.32±31.61 |
| Medial Head of Gastrocnemius Muscle | 74.56±36.73 | 99.16±42.26 | 90.52±51.24 |
| Tibialis Anterior Muscle | 38.80 ±33.39 | 42.83 ±38.21 | 41.69 ±24.26 |

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*Table 6: Statistical analysis of integrated EMG in the Whole Aerial Process*

| | | Sum of Squares | df | Mean Square | F | p |
|---|---|---|---|---|---|---|
| Gluteus Maximus | Between Groups | 7517.399 | 2 | 3758.7 | 0.958 | 0.406 |
| | Within Groups | 58844.416 | 15 | 3922.961 | | |
| | Total | 66361.815 | 17 | | | |
| Biceps Femoris Muscle | Between Groups | 5289.196 | 2 | 2644.598 | 3.24 | 0.068 |
| | Within Groups | 12242.04 | 15 | 816.136 | | |
| | Total | 17531.236 | 17 | | | |
| Rectus Femoris | Between Groups | 4411.727 | 2 | 2205.863 | 5.196 | 0.019 |
| | Within Groups | 6368.538 | 15 | 424.569 | | |
| | Total | 10780.265 | 17 | | | |
| Lateral Head of Gastrocnemius Muscle | Between Groups | 369.857 | 2 | 184.929 | 0.127 | 0.882 |
| | Within Groups | 21863.719 | 15 | 1457.581 | | |
| | Total | 22233.576 | 17 | | | |
| Medial Head of Gastrocnemius Muscle | Between Groups | 1869.138 | 2 | 934.569 | 0.487 | 0.624 |
| | Within Groups | 28801.955 | 15 | 1920.13 | | |
| | Total | 30671.093 | 17 | | | |
| Tibialis Anterior Muscle | Between Groups | 51.82 | 2 | 25.91 | 0.025 | 0.976 |
| | Within Groups | 15818.484 | 15 | 1054.566 | | |
| | Total | 15870.304 | 17 | | | |

As can be observed from Table 5 and 6 above, it is concluded that $F(2,17)= 5.196$, $p=0.019‹05$, which reveals that there are significant differences in the impact of the three take-off modes of shallow squat, half squat and deep squat on the rectus femoris. Through back testing (LSD), it is concluded that there are significant differences in the impact of deep squat and shallow squat on the rectus femoris ($p = 0.019$). However, there are no differences in other muscles. The above diagram of integrated EMG value shows numerical differences of the integrated EMG value between shallow squat and deep squat, and the following figure of muscle mobilization sequence obviously shows the differences of the rectus femoris between shallow squat jumps and deep squat jumps in time dimensions, which completely accords with the analysis results. The reason for this result in the aerial phase lies in that the rectus femoris continues to carry out pedal-stretch after the body leaves the ground. In the process of aerial for blocking, the human body stretches out of the net with both arms. To keep the body balanced in the air, both legs must continue pedal-stretch forward to make the body into a "bow" subtype, which is more conducive to maintaining the body balance. To make the legs continue to pedal-stretch, it is required for the rectus femoris to continue to contract, which suggests that the rectus femoris is the primary muscle to maintain body balance. Shallow squat and deep squat stay in the air for different time and heights, which is also a reason for numerical accumulation.

### *6.2 Muscle Mobilization Sequence in the Whole Aerial Process*

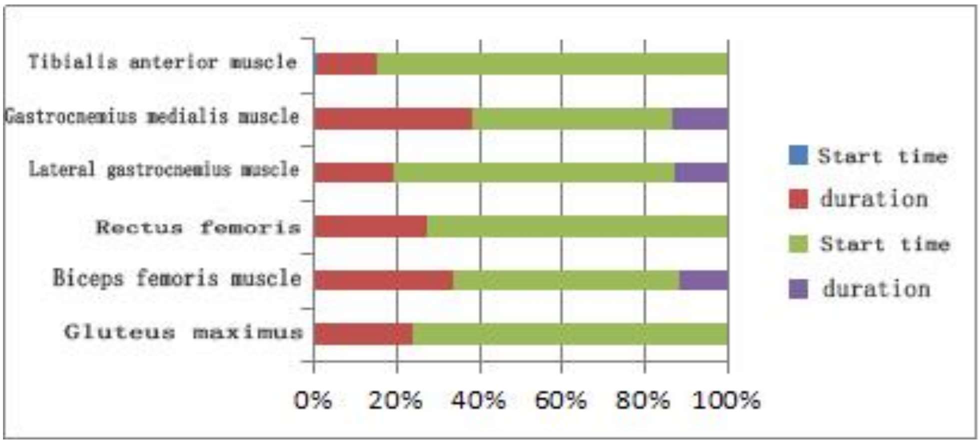


*Figure 8: Muscle Discharge Sequence of Shallow Squats in Aerial*

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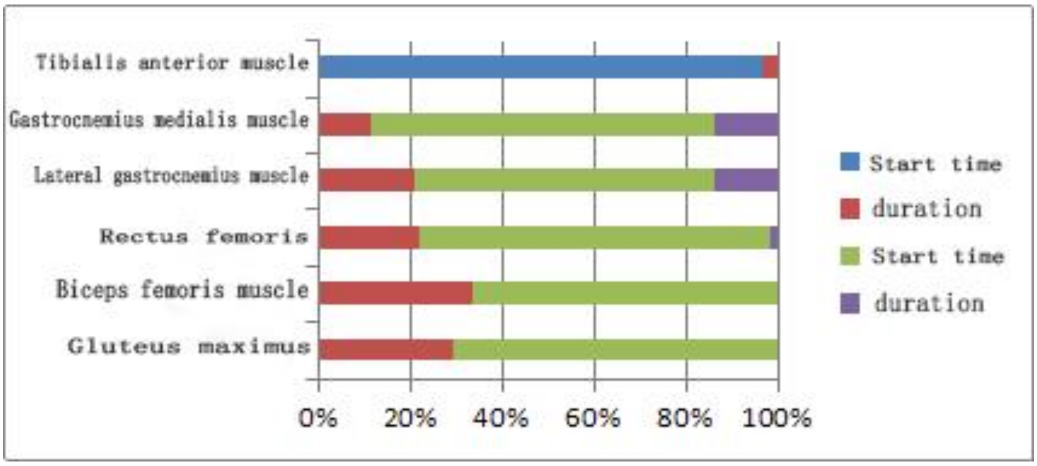


*Figure 9: Muscle Discharge Sequence of Half Squats in Aerial*

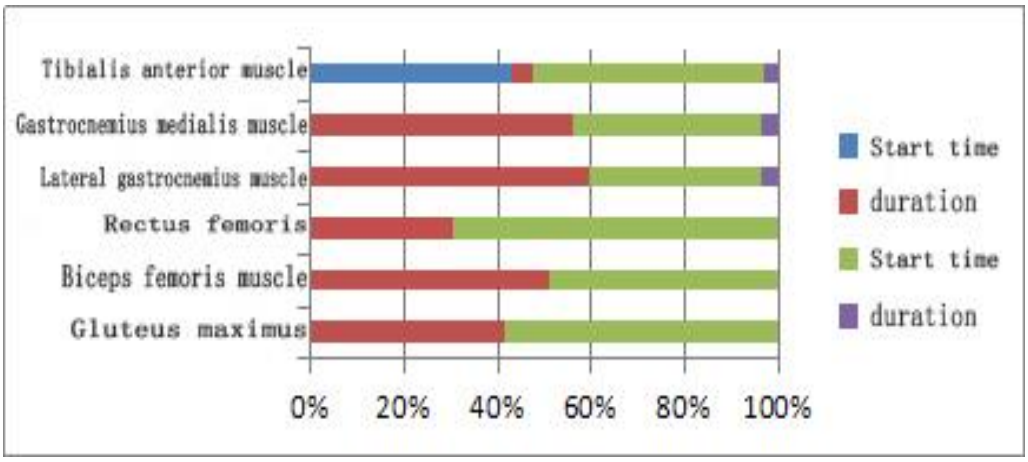


*Figure 10: Muscle Discharge Sequence in Deep Squat Aerial*

As can be seen from Figures 8, 9 and 10,the above three diagrams of muscle mobilization sequence show that, except for the tibialis anterior muscle, which takes off from half squat, all the other muscles exert force in the first half of the aerial. The main reason for this phenomenon is that the muscles of the body need to maintain balance during the aerial ascent and stay in the air (and the hang time), so the muscles need to exert force to maintain the body balance in the air, and the force exertion will appear in the first half. The tibialis anterior muscle is always in a relaxed state during the aerial, and there is no discharge as shown in the figure. During the aerial phase of half squat for take-off and deep squat for take-off, the sequence of force exertion of muscles shows a high degree of consistency. In the phase of shallow squat, except the differences in the lateral head of gastrocnemius muscle, there is a high degree of consistency in the time and sequence of force exertion of other muscles. It is only in the final phase of half squat and aerial that the tibialis anterior muscle appears to exert force, which is caused by the athletes' stretching their feet to prepare for landing.

## 7. EMG Analysis of Landing Phase

### *7.1 Integrated EMG Value of the Whole Falling and Landing Phase*

*Table 7: Integrated EMG Value When Falling to the Ground ($\bar{x}\pm s$) n=6*

| | Shallow Squats | Half Squats | Deep Squats |
|---|---|---|---|
| Gluteus Maximus | 38.62±34.38 | 58.85±20.05 | 60.42±57.26 |
| Biceps Femoris Muscle | 13.39±9.52 | 27.87±27.53 | 26.89±23.39 |
| Rectus Femoris | 25.15±15.19 | 30.14±13.45 | 56.33±37.49 |
| Lateral Head of Gastrocnemius Muscle | 31.01±16.34 | 39.54±23.76 | 59.01±47.29 |
| Medial Head of Gastrocnemius Muscle | 45.87±7.63 | 58.55±17.09 | 66.20±28.56 |
| Tibialis Anterior Muscle | 30.20±19.81 | 47.19±22.35 | 76.89±31.04 |

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*Table 8: Statistical analysis of integrated EMG Value When Falling to the Ground*

| | | Sum of Squares | df | Mean Square | F | p |
|---|---|---|---|---|---|---|
| Gluteus Maximus | Between Groups | 3,025.889 | 2 | 1,512.945 | 0.756 | 0.487 |
| | Within Groups | 30,027.153 | 15 | 2,001.810 | | |
| | Total | 33,053.043 | 17 | | | |
| Biceps Femoris Muscle | Between Groups | 131.111 | 2 | 65.555 | 0.103 | 0.902 |
| | Within Groups | 9,517.881 | 15 | 634.525 | | |
| | Total | 9,648.992 | 17 | | | |
| Rectus Femoris | Between Groups | 3,126.811 | 2 | 1,563.406 | 2.314 | 0.133 |
| | Within Groups | 10,135.678 | 15 | 675.712 | | |
| | Total | 13,262.489 | 17 | | | |
| Lateral Head of Gastrocnemius Muscle | Between Groups | 2,470.710 | 2 | 1,235.355 | 1.208 | 0.326 |
| | Within Groups | 15,341.425 | 15 | 1,022.762 | | |
| | Total | 17,812.135 | 17 | | | |
| Medial Head of Gastrocnemius Muscle | Between Groups | 1,265.481 | 2 | 632.741 | 1.628 | 0.229 |
| | Within Groups | 5,829.403 | 15 | 388.627 | | |
| | Total | 7,094.885 | 17 | | | |
| Tibialis Anterior Muscle | Between Groups | 6,701.157 | 2 | 3,350.579 | 5.418 | 0.017 |
| | Within Groups | 9,276.702 | 15 | 618.447 | | |
| | Total | 15,977.859 | 17 | | | |

As can be observed from Table 7 and 8 above, it is concluded that $F(2,17)=5.418$, $p=0.017‹05$, which reveals that shallow squat, half squat and deep squat have significant differences on the tibialis anterior muscle. Through back testing (LSD), it is concluded that there are significant differences in the impact of deep squat and shallow squat on the tibialis anterior muscle ($p=0.017$). It is consistent with the previous research. For the downward buffer, whether it is in-situ downward buffer or landing and buffer from the air, the effects of deep squat and shallow squat on the tibialis anterior muscle are significant.

### *7.2 Muscle Mobilization Sequence when Falling on the Ground*

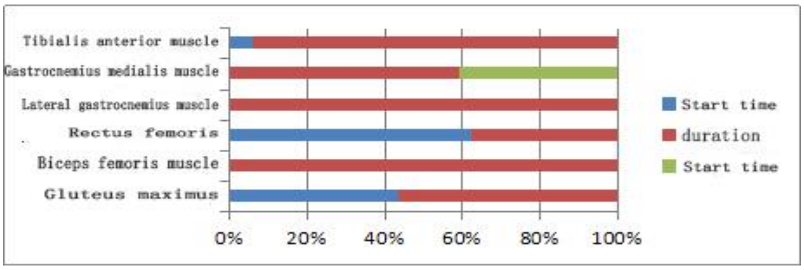


*Figure 11: Muscle Discharge Sequence during Shallow Squat for Landing*

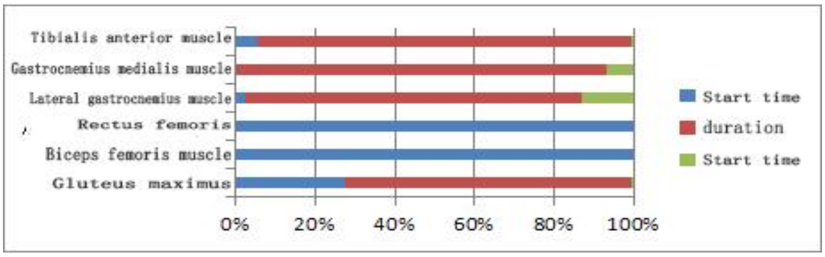


*Figure 12: Muscle Discharge Sequence during Half Squat for Landing*

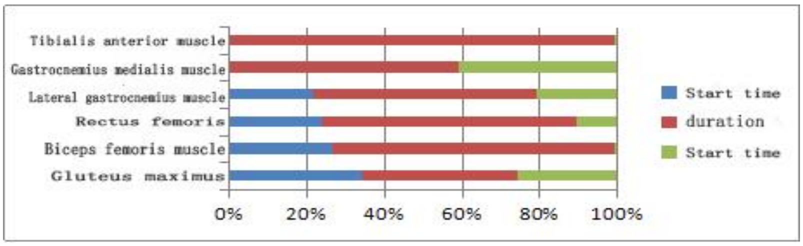


*Figure 13: Muscle Discharge Sequence during Deep Squat for Landing*

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As can be seen from Figures 11, 12 and 13,the above three diagrams show that there are obvious differences and consistency in muscle discharge sequence among the three, but the discharge sequence of shallow squat, half squat and deep squat is consistent within their respective movements. The difference lies in the biceps femoris muscle, which does not discharge continuously during half squat for landing, but shows continuous or intermittent discharge during shallow squat and deep squat for landing; the consistency is manifested in the lateral head of gastrocnemius muscle, and the force exertion is all obvious during shallow squat, half squat and deep squat. The consistency within each movement, such as the tibialis anterior muscle, rectus femoris and gluteus maximus during shallow squat, shows the consistency of discharge sequence; the medial head of gastrocnemius muscle, biceps femoris muscle and gluteus maximus show obvious consistency during half squat. The tibialis anterior muscle, rectus femoris, biceps femoris muscle and gluteus maximus of deep squat show consistency. Moreover, there are also differences in each movement, such as the medial head of gastrocnemius muscle, biceps femoris muscle and rectus femoris during deep squat, in the persistence of discharge.

Zhan Jianguo, Dai Xinghong and Zhang Guofeng[4] found that the discharge of each muscle is different in the process of exercise through the EMG study of the posterior thigh muscle group of short distance runners, so the future force training should be designed and conducted in view of professional and technical characteristics, so that the training means can be more in compliance with the laws of special sports.

## 8. Conclusion

There are significant differences in the impact of deep squat and shallow squat on the tibialis anterior muscle during squat (p=0.027‹05); significant differences in the impact of deep squat and shallow squat on the tibialis anterior muscle in the landing phase (p=0.017), and significant differences in the impact of deep squat and shallow squat on the tibialis anterior muscle whether during in-situ downward buffer or landing and buffer from the air. The impact of deep squat and half squat on the tibialis anterior muscle in the pedal-stretch phase is significantly different (p=0.001‹05); there are significant differences in the impact of deep squat and shallow squat on the rectus femoris (p=0.015‹05). Anatomically, it is known that the rectus femoris is the primary motor muscle of knee extension. There are significant differences in the impact of deep squat and shallow squat on the rectus femoris in the aerial phase (p=0.019), which requires the rectus femoris to continue to contract, indicating that the rectus femoris is the primary muscle to maintain body balance.

Since the rectus femoris is the primary knee-extension muscle, and the role of buffer and immobilization determines the take-off height to a certain extent, to effectively raise the bounce height, it is advisable to strengthen the force training of rectus femoris and prevent sports-related injuries. The rectus femoris is the primary muscle to maintain the body balance, and the medial head of gastrocnemius muscle and the lateral head of gastrocnemius muscle play a key role in maintaining the body balance in the air. Thus, it is recommended to strengthen the coordination training between muscles to boost the working efficiency of muscles.

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