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Research on the characteristics of lower limb electromyography and fatigue of 400m Sprinters

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Abstract: *the main muscle groups in the non-terminal straight line were gastrocnemius muscle, biceps femoris muscle, lateral femoris muscle and medial femoris muscle; The range of the main muscle groups during the entire cushioning and thrusting and extension phases is very stable. The cushioning phase is the gastrocnemius, biceps femoris, tibial anterior muscle, and lateral femoris; the thrusting and extension phases are the medial femoris, lateral femoris, and biceps femoris, Gastrocnemius; Rhythm has no significant difference in the MPF of each muscle group in the non-end-point straight and the end-point straight (P>0.05), and the MPF of each muscle group in the end-point straight has a downward trend.*

Keywords: *400m running;sEMG;muscle strength characteristics;muscle fatigue*

1. Introduction

400m is a long-distance event in sprint. High level athletes need not only excellent speed quality, but also highly developed lactate endurance quality and scientific and stable speed rhythm. There is no doubt that scientific research is the most effective way to speed up the recognition of project characteristics. The extensive application of sEMG technology in the field of sports science research in the past 20 years has proved that it has become a reliable means to study the main muscle groups and muscle strength characteristics of the project. Therefore, with the help of wireless surface electromyography, this paper will explore the characteristics of lower limb muscle strength and fatigue of 400m sprinters, enrich the special theory and provide reference for sports training practice.

Foreign scholar A.Nummela et al found that the muscle activity of gastrocnemius (GA) and lateral femoral muscle (VL) increased gradually at 400 meters. The increase of iEMG was due to the increase of burning rate and the addition of additional motion units to compensate muscle fiber contraction. Sexual failure; in the second half of the 400-meter period, since the fast muscle fiber is more prone to fatigue than the slow muscle fiber, the relative proportion of the slow muscle fiber in the force generation increases, which may be one of the reasons why the 400-meter movement speed is getting slower and slower[1].Kyröläinen H et al. Found that in order to effectively improve running speed and generate more powerful force in the best direction, we need to increase the EMG activity of two joint muscles (biceps femoris, rectus femoris and gastrocnemius) throughout the running cycle[2].In this paper, we use the peak electromyography of each muscle group to standardize the RMS electromyography of muscle group.

According to previous studies, researches on muscle activation sequence have shown the original surface electromyography and made a statistical table of the moment of activation. This paper mainly adopts the method of De Koning JJ et al , which is divided into two steps: first, standardize the amplitude and time of three consecutive steps of the original EMG flow value, and the amplitude standardization is to divide the EMG amplitude of each column by the muscle in this column[3]. The maximum amplitude of electromyography is normalized. Time standardization refers to that each column of electromyogram amplitude is divided into 100 equal parts by MATLAB software, and the average value of the amplitude in each section is taken for time normalization. Finally, three steps of superposition average are carried out to get the single step standardized average electromyogram. Secondly, the sequence diagram of muscle activation is analyzed by origin 8.0. In this study, a representative athlete was selected for analysis and muscle activity diagram was drawn. In this paper, we use the peak electromyography of each muscle group to standardize the RMS electromyography of muscle group[4].

When muscles contract continuously for a period of time, their physiological characteristics are changed, resulting in the temporary decline of the maximum working ability or the maximum contracting ability caused by muscle activity, which is called muscle fatigue[5] Some studies have shown that, in the static or dynamic exercise situation, with the occurrence of exercise muscle fatigue, the Fourier spectrum curve of sEMG signal can shift to the left in varying degrees and lead to the corresponding decline of MPF and MF which reflect the characteristics of the spectrum curve[6-7]. For the first time, K. Kogi and other foreign scholars analyzed the frequency of EMG signal to monitor muscle fatigue. They observed the transition from the power spectrum of surface EMG signal to the low frequency[8]. Hagberg et al. Discussed the relationship between the power spectrum of elbow flexion and muscle contraction, measured the changes in the process of isometric contraction under the increasing load resistance, and found that the frequency domain index MPF value increased with the increase of contraction force under the condition of low load level, and the results were different under the condition of large load[9]. BJ ö RN et al. Studied the changes of shoulder surface electromyography during equal length forward flexion, and found that the MPF values of trapezius, deltoid, infraspinatus and biceps brachii had no significant difference and decreased gradually[10]. In the past, the mainstream view was that in the final sprint stage of 400m, the body muscle activity has reached the limit load condition, resulting in the decrease of MPF value. However, at present, there is no recognized frequency value as the standard to judge the generation of fatigue, and the EMG activity of other muscles has increased, which may be due to the secondary respiration and muscle compensation, through the recruitment of more sports units. In order to compensate for the deficiency of muscle fiber contractility that has been recruited, it is consistent with the results of nummela et al[1].

2. Methodology

2.1 Sudjects

In this paper, 10 second-class 400m runners from the College of physical education of Jiangxi Normal University are selected as the research objects. The basic information is: average age is 20.8±0.4y, height is 181 ± 4.6cm, weight is 65.8±7.7kg, training period is 5.8±0.4y. Training period: 5.8±0.4y.ALL participants were in good physical condition.Prior to the investigation,they were informed of the experiment risks and signed an informed consent document.

2.2 Produce

Each subject conducted three 400m tests. The test requirements were:Rhythm 1 (self-rhythm); Rhythm 2 (fast in the front and slow in the back); Rhythm 3 (slow in the front and fast in the back); The setting of Rhythm 2 and Rhythm 3 is based on the research of P J. Saraslanidis et al.The standard of slow forward is determined by subtracting 0.5-1 second from the 200 meters ahead of self-tempo[11]. Early rhythm perception training also showed that most athletes can accurately control this interval.(1)The athlete runs 400 meters at his own pace and monitors his main muscles and muscle fatigue characteristics;(2)The rhythm method is mainly to improve the performance of the first 200 meters in the self-paced 400 meters to increase the performance by 0.5s-1s, and try to finish the latter course;(3)Rhythm mode requires all subjects to reduce 0.5s-1s in the first 200 meters in the 400 meters self-paced run, and try their best to finish the end.

In order to prepare for the sprint test, the subjects participated in the training for one semester, including 2-3 times a week. Training focuses on the perception and sensitivity of athletes to their own rhythm. The test time is divided into three tests, one test interval is one day off. Before each test, 30 minutes of general preparatory activities and special preparatory activities should be carried out, mainly including jogging and stretching, and the body should sweat slightly.

2.3 EMG test

The 400m field test was carried out on the 400m standard track and field track. In the fourth run, the first research stage is the EMG signal of the left leg 1-3 steps continuously when the athlete enters 125 meters of the non terminal straight, and the second research stage is the EMG signal of the left leg 1-3 steps continuously when the athlete enters 370 meters of the terminal straight. In the process of athletes'

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test, two staff members, one riding electric vehicle, one holding computer and external camera synchronize the EMG and video, and the electric vehicle and athletes are controlled at a distance of 3-4m for tracking and shooting. Instrument: US Delsys 16 lead wireless electromyography tester, sampling frequency: 1000Hz. Muscle selection: select 8 representative left upper and lower limb muscles: vertical spine muscle, gluteus maximus muscle, biceps femoris muscle, medial head of gastrocnemius muscle, rectus femoris muscle, medial femoris muscle, lateral femoris muscle, anterior tibia muscle.

3. Statisical analyses

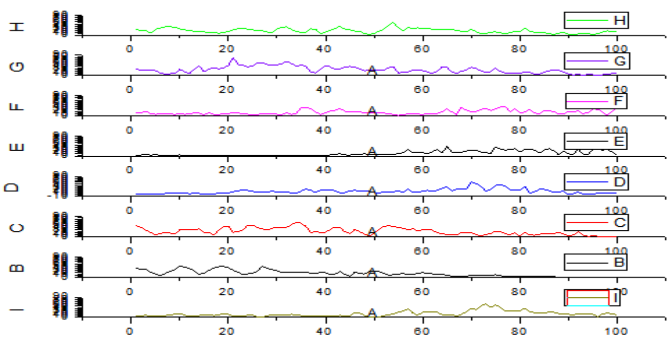
The original EMG data was processed by the analysis software of dalsys EMG tester. Firstly, the original EMG data collected by the EMG test system was filtered by band-pass filter (cut-off frequency 30-480hz), and the data was segmented in combination with video synchronization. In order to eliminate signal interference, the original EMG signals of the left leg at 125m and 370m were collected for three consecutive action periods. The original EMG data were processed by amplitude normalization and time normalization in MATLAB software, and the muscle activation sequence diagram was made in origin 8 software. In SPSS 16.0, paired sample t-test was used to analyze the change of MPF value on non-terminal straight and terminal straight. The data was indicated by mean ± SD, and the significant difference was indicated by $P \le 0.05$.

4. Result

It can be seen from table 1 that the main muscle groups for doing work are almost the same in the non-terminal straight line buffering and stretching stages, mainly including the medial head of gastrocnemius, biceps femoris, lateral femoris and medial femoris, while the main muscle groups for doing work in stretching stage are more mobilized than that in buffering stage.

Table 1 Percentage of work done by muscles in each muscle group of athletes in the buffer and stretching stages (n = 10)

	Erector spinalis	gluteus maximus	biceps femoris	gastrocnemius	rectus femoris	medial femoris	lateral femoris	anterior tibia
Mean±SD (cushioning)	7.3±3.8	10.3±7.6	18.8±7.9	20.9±12.9	4.4±2.8	13.5±4.9	13.6±6.9	10.8±4.5
Mean±SD (stretching)	7.4±4.4	5.6±3.2	12.3±7.8	24.8±5.1	7.7±4.2	16.7±7.0	14.4±5.1	10.6±5.7



Figue.1 Standardized EMG in non terminal straight buffering phase(I:anterior tibial muslce;B:vertical spine muscle;C:gluteus maximus;D:bicepes femoris;E:medial head of gastrocnemius;F:rectus femoris;G:medial femoris;H:lateral femoris)

It can be seen from Figure 1 that the rectus femoris, gastrocnemius medialis, biceps femoris and tibialis anterior muscles are basically in a resting state at 0-40% time, while the erector spinalis, gluteus maximus, medial femoris and lateral femoris muscles are activated, which indicates that the left foot contracts actively when it lands, and the muscles are actively forced to form; the rectus femoris is inactivated at 50% - 60% time; the erector spine is inactivated at 80% time, and the left foot is at 70% time. Vertical support status.

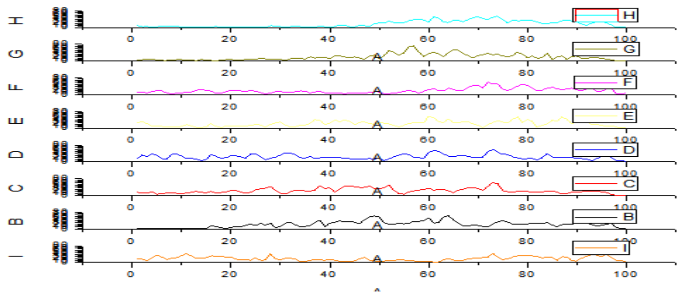


Figure. 2 Standardized electromyography in non terminal straight leg stretch stage

Figure 2 shows the standardized EMG of athletes in the non-terminal straight leg stretch stage. It can be seen from the figure that the tibialis anterior muscle, gluteus maximus, biceps femoris, gastrocnemius medial head and rectus femoris are activated during the stretch; the lateral femoris and medial femoris are activated at 40% of the time; the vertical spine muscle is activated at 20% of the time; the rectus femoris is activated at 40% - 60% of the time; the tibialis anterior muscle is deactivated at 60% of the time. When male athletes push and stretch, their EMG activities show strong coordination and timing.

Table 2 Changes in MPF value of athletes in the non-finish straight and the buffer phase of the finish straight (n=10)

	Erector spinae	Gluteus maximus	Biceps femoris	Medial head of gastrocnemius	Rectus femoris	Medial femoris	Lateral femoral muscle	Tibialis Anterior Muscle
Non-finish straight	88.7±19.2	63.5±24.1	82.5±12.4	102.0±26.1	80.6±24.2	76.2±22.6	93.9±31.4	84.2±18.6
Finish straight	71.2±16.6	68.7±15.0	73.0±14.3	90.0±16.9	84.4±20.7	74.7±20.1	80.9±15.9	77.5±17.3
t	4.293	-0.685	1.160	1.898	-0.407	0.822	1.152	0.878
P	≤0.05*	>0.05	≤0.05*	>0.05	>0.05	>0.05	>0.05	>0.05

As shown in Table 2, in the buffering stage, with the increase of exercise time, except for the increase of MPF value of erector spinalis and rectus femoris, the MPF value of other six muscles basically showed a downward trend as a whole, and there was significant difference between erector spinalis and biceps femoris in buffering process ($P \leqslant 0.05$), but there was no significant difference in the MPF value of other muscles in buffering process ($P > 0.05$).

Table 3 Changes in MPF value of athletes at the non-finish straight and the finish straight at the kicking stage (n=10)

	Erector spinae	Gluteus maximus	Biceps femoris	Medial head of gastrocnemius	Rectus femoris	Medial femoris	Lateral femoral muscle	Tibialis Anterior Muscle
Non-finish straight	84.6±33.6	71.4±25.1	100.8±22.5	92.1±19.7	82.5±25.7	77.3±24.5	90.9±17.0	85.5±14.8
Finish straight	80.6±22.1	79.0±19.1	88.7±34.5	95.9±35.3	76.4±18.5	87.0±30.2	77.7±24.8	79.1±30.4
t	0.283	-1.035	1.151	-0.408	0.661	-0.857	1.422	0.714
P	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05

Table 3 shows the MPF values of athletes in the non-terminal straight and the terminal straight. It can be seen from table 6 that the MPF values of athletes in the pedaling and stretching stage show a decreasing trend due to the prolongation of exercise time. The MPF values of vertical spine muscle, biceps femoris muscle, medial head of gastrocnemius muscle, rectus femoris muscle, lateral femoris muscle and anterior tibia muscle in the terminal straight are lower than those in the non-terminal straight, and the MPF values of gluteus maximus muscle and medial femoris muscle are obvious. There was no significant difference between the two groups ($P > 0.05$).

5. Conclusion

The main strength muscles of 400 meter athletes in the non terminal straight support period are: gastrocnemius medial head, biceps femoris, medial femoris and lateral femoris. According to the anatomical and physiological characteristics of gastrocnemius, after landing on the ground, the ankle

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joint flexed, and the gastrocnemius muscle contracted centrifugally to better complete the buffering task. During the buffering, the front thigh muscles play an important supporting role, making the left leg complete the centrifugal contraction and buffering most of the reaction force at the moment of landing, which can not only protect the knee joint well, but also play the role of bending the hip and extending the knee. Biceps femoris is also a large muscle in the whole percentage of work done by the muscle. When landing and buffering, it mainly contracts to the center, and when pedaling and stretching, it transits to centrifugal contraction, so as to complete the work of extending the hip and bending the knee.

With the increase of exercise time, the MPF value of each muscle group decreased. When buffering, the medial head of gastrocnemius and the lateral thigh muscle decreased most obviously, which is related to the function of gastrocnemius muscle. The MPF values of the erector spine, biceps femoris, medial head of gastrocnemius, rectus femoris, lateral femoris and anterior tibial muscle in the end-point straight line decreased, but there was no significant difference compared with the non end-point straight line ($P>0.05$).As mentioned earlier in the article, the main working muscles in the whole support stage are the medial head of gastrocnemius, biceps femoris, medial femoris and lateral femoris, which shows that these muscles maintain a high-intensity discharge phenomenon in the whole support process and always participate in the movement of hip joint.

From the test results, there seems to be no significant difference in the MPF of each muscle group in the two straight segments. However, regardless of the rhythm, the MPF of each muscle group at the end point straight segment showed a downward trend compared with the non-end point straight segment. We know that the sample size and standard deviation have a greater impact on the P value. From the measured data, it can be found that the larger standard deviations at different stages of each muscle group may be the direct cause of the non-significant difference between before and after MPF. Therefore, grasping the general trend of MPF changes in this case is more conducive to correctly analyzing changes in muscle fatigue. 400 meters is the longest sprint event in sprint sports, which has strong requirements for athletes' physical fitness, skills, and energy supply methods. As mentioned in the previous article, blood lactic acid rises, resulting in insufficient energy metabolism and energy supply. However, after 10 minutes of intermittent rest, the heart rate and blood lactic acid gradually recovered. Explains that in training, interval training should be used, and strict requirements on the movement structure, load intensity, and interval time should be put forward, so that the body is in a state of incomplete recovery. Repeated exercises will cause the athlete to experience exhaustion. There may be more obvious differences in activity frequency.Kyröläinen et al.research showed that the EMG signal of the posterior femoral muscles of the lower limbs is not obvious when the subject is running at a constant speed, but as the running speed continues to increase, the EMG signal begins to produce greater fluctuations[2]. The EMG signal gradually weakens when the muscles are fatigued in the later course. This phenomenon shows to a certain extent that the posterior thigh muscles are the main source of strength for running. It is necessary to effectively increase the running speed and produce more energy in the best direction. Strong strength is needed to improve the electromyographic activity of both joint muscles (biceps femoris, rectus femoris and gastrocnemius) throughout the running cycle. Larivière et al.evaluated whether a 10 or 15-minute rest interval can fully recover the back muscles after fatigue contraction from the perspective of electromyography (EMG). They found that the muscles were full recovery[12]. Nummela et al. (1992) tested the surface electromyography and step length characteristics of 6 male sprinters running 100 meters, 200 meters, 300 meters and 400 meters at a speed of 400 meters, and analyzed the changes of blood lactic acid (Bla)[1]. And after resting and after each sprint, electromyography (EMG) registration was carried out.

The study showed that the muscle activity of gastrocnemius and lateral femoris muscles gradually increased, and fast muscle fibers were more likely to be fatigued than slow muscle fibers. Therefore, under high-intensity, high-load exercise training, muscle fatigue occurs, and with the prolongation of exercise time, the MPF is in a downward trend.

The 400m long run is the most difficult stage in the competition. No matter in the process of buffering and stretching, the MPF value of each muscle group of the lower limbs gradually decreases, and the muscle fatigue state is obvious. Therefore, the athletes need to strengthen the muscle endurance of gluteus maximus, rectus femoris, lateral femoris and anterior tibial muscles during the long run.

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