Surface-EMG analysis for the Lower Limb Muscle Characteristics of Top Level Women Speed Skater in Short Distance

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ABSTRACT. Purpose: *To insight into the lower limb muscle characteristics of top level speed skater in short distance, in terms of iEMG, excitation intensity, and activation modality.* ***Methods:*** *Three female word champion speedskaters participated in this study. EMG data was collected in the second straight by ME6000 when gliding in a standard speed skating rink.* ***Results:*** *tibialis anterior and quadriceps muscle are the main work muscles in supporting phase; The excitation intensity of tibialis anterior and biceps femoral is bigger in flexion phase, while others(gastrocnemius lateralis , vastus medialis, vastus lateralis, rectus femoris, semitendinosus muscle and gluteus muscle) are bigger in extension phase; the onset of tibialis anterior is first, followed by the vastus medialis, vastus lateralis and biceps femoral; the offset of tibialis anterior is first, then the vastus medialis, vastus lateralis and gastrocnemius lateralis at the time of off-ice.* ***Conclusion:*** *The main work muscles is consistent in elite athletes; muscle activation modality is regular in the same technique in elite athletes; Elite athletes' technique is very stable. Short -track speed skaters should put more punch on gastrocnemius strength training when switch to speed skater.*

KEYWORDS: *Speed skating; muscle characteristics; iEMG; RMS; activation modality*

1. Introduction

Muscle characteristic refers to the mechanical and electromyographic characteristics of muscle in the process of completing a technical motor. It is an important means to study and grasp the characteristics of the sport, and an important reference index and test standard for selecting and designing the strength training interventions. Therefore, in recent years, there have been a lot of studies on the characteristics of muscle in various sports, such as Annachiara Strazzaa(2017)[1], YIN Hua-gen(2018)[2], WANGHuihui(2019)[3], and Liu Lixin(2019)[4]. However, compared to the summer Olympic events, the focus on winter sports needs to be

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improved. Although, some author had researched speed skaters' muscle characteristic [5], more quantified information about top level athletes need to be unveil.

CHEN Xiao-ping(2004)[6] have pointed out that the specificity of various training methods can be examined from three aspects: first, whether the main work muscles in strength exercises are consistent with the technique; second, whether the activation intensity and the way of work done by the main work muscles are close to the requirements of the technique; third, whether the activation order of participating muscle is similar to that of the technique. Therefore, in order to provide more guidelines for the selection and design of future strength training methods, the study selected the main work muscle, muscle exciting intensity and activation modality and other EMG indicators to study and analyze the characteristics of lower limbs muscle during the process of gliding, as the benefit of surface electromyography were non-invasiveness and easy to implement[7][Kamila Mortka et al,2020].

2. Material & methods

2.1 Participants

Three top world class female short distance speed skaters participated in this study. There were Wang Beixing, Yu Jing and Zhang Hong who came from china national speed skating team in Sochi Olympic cycle, represents the highest level of china in the last decade. Wang Beixing won the bronze medal of the women's 500m event in the 2010 Winter Olympics and won Championships in World Cup and World many times; Yu Jing was the former world record holder and the first woman athlete glided into 37 seconds; Zhang Hong won the gold medal in Sochi Winter Olympics women's 1000m. The study was conducted in accordance with ethical standards of the local school. All participants gave their written informed consent to the experimental procedures after having the possible risks and benefits of participation explained to them.

2.2 Procedures

The test was performed in a standard speed skating rink in HaErBin in china , which is approved for international competitions. According to the previous study, the second half section of the second straight belong to the high speed stage. Therefore, the athletes stand on the outer starting line to start, after about 200 meters acceleration and then into the data collective area.

Surface EMG was measured from the tibialis anterior (TA), gastrocnemius lateralis (GL), vastus medialis (VM), vastus lateralis (VL), rectus femoris (RF), biceps femoral (BF), semitendinosus muscle (SEM) and gluteus muscle (GM) of both lower limbs by ME600(Mega Company 16-channel wire telemetering electromyography) and synchronously with the HD camera which placed inside the

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rink stationary(Panasonic.AG-DVC33,50 Hz).After shaving, abrading and cleaning the skin, pairs of Ag/AgCl surface electrodes which placed with 20mm of centre-to-centre spacing were used. The electrode was attached on the belly of the muscle and the reference electrode was located 20 mm distally according to SENIAM recommendations. The EMG raw signal was amplified by preamplifier(305times) which had a common mode rejection ratio of 110 dB, the input impedance >1.0 GV, sampling frequency was 1000 Hz and band-pass filtered (8-450 Hz), A/D conversion 14 bits. The signal will full-wave rectified for the further research.

After 30 minutes warm up the athletes applied electrode pasted. The portable electromyography instrument was fixed to the back of the athlete's waist, preamplifiers and cables were fixed with tape and net bandages, to avoid movement artefacts. When all the equipment was attached, subjects performed specific warm-up on ice 5 minutes and checked the synchronization between the camera and ME 6000. Each skater skated twice subsequent trials at maximal effort in a 400-m lap, interval 10 minutes, the lap time results in the daily training level between 120-130%, take the better one to analyze.

2.3 Data processing

Video combined with EMG was used to judge the action phase of flexion and extension during gliding. Using the data conversion function of MEGA WIN, the original electromyography of different phases was transformed into RMS electromyography (Root Mean Square ,RMS), the average conversion period was 0.01 seconds, the mean RMS and RMS area(iEMG)were calculated. Electromyography amplitude standardization was carried out using the maximum RMS electromyography of each muscle in the whole testing. Konging JJ(1991)[5] and HUANG Da- wu(2015)[8] methods were adopted which divided into two steps to judge the muscle activation modality: firstly, in order to exclude the specificity of a single stroke electromyography, the amplitude and time of each single stroke electromyography were normalized, and then the mean normalized electromyography was obtained after three single stroke was standardization. The abscissa was set from 25% in origin 7.0, when EMG signal surpass 10% of the horizontal axis, some muscle was considered in activating (GUOFeng,2011;ZHAO Wei-ke,2011)[9-10]. Secondly, because the maximum electromyography in the whole testing was to normalize amplitude, even if some muscle electromyography signal is minor in the whole supporting phase, we may still see them in the activated state for a long time in the figure completed in the first step above. Therefore, in order to exclude this false phenomenon, we qualitatively judge the activation state of the related muscles according to the RMS curve (the pictures obtained by the root mean square can very intuitively see the starting and ending points of muscle, LI Yan-jun,2010)[11], so as to complete the correction of the first step and obtain the final muscle activation modality.

In order to reduce external interference and eliminate the instability of EMG itself, the paper used the methods of CAO Hui(2005)[12] and LIN Jia(2006)[13] to deal

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with the dynamic RMS EMG. First, the EMG of each muscle was normalized by peak RMS EMG, the absolute EMG value was converted to the relative EMG value between 0 and 1. Then the relative myoelectric value was normalized with 100 equal completion time using cubic spline interpolation. After the amplitude and time normalized, the mean EMG models of each muscle was obtain from three strokes, Pearson correlation analysis was used between averaged EMG and single stroke. Finally, three correlation coefficients of each muscle were averaged, and the mean correlation coefficients of each muscle in individual model were obtained.

3. Results

3.1 iEMG

Table 1 iEMG of each muscle in straight from Yu Jing left leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	13.85	4.84	19.26	25.43	5.98	14.00	12.00	4.65
	E	5.86	6.05	23.16	25.90	4.73	10.96	17.86	5.48
2step	F	12.62	4.06	18.06	28.52	4.93	13.22	13.57	5.01
	E	5.95	10.51	25.17	23.19	3.87	12.59	14.17	4.56
3step	F	15.32	3.78	22.11	32.40	3.78	14.45	7.75	3.39
	E	6.59	7.00	21.74	24.59	4.21	10.19	20.04	5.64

Flexion(F) and extension(E) were two phase in supporting process, F was from landing to knee angle increasing, E was from knee angle increasing to uncontacted.

Table 2 iEMG of each muscle in straight from Wang Bei-xing left leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	19.18	3.30	36.47	17.77	4.10	11.37	4.91	2.89
	E	10.09	7.40	34.35	18.46	4.95	14.73	5.75	4.28
2step	F	19.59	4.19	35.63	17.46	3.89	11.03	4.72	3.48
	E	9.90	8.03	36.41	16.29	4.04	15.81	5.07	4.45
3step	F	16.12	3.66	36.96	18.08	4.83	12.51	5.04	2.81
	E	10.11	10.62	33.25	15.57	4.65	13.11	8.88	3.81

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Table 3 iEMG of each muscle in straight from Zhang Hong left leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	25.56	2.28	15.35	16.34	5.75	25.71	4.11	4.90
	E	12.49	6.24	27.58	15.40	6.66	16.34	6.45	8.84
2step	F	23.45	3.02	15.03	15.25	5.98	28.11	4.76	4.39
	E	11.94	7.12	33.52	13.55	6.77	13.32	7.35	6.43
3step	F	28.01	3.12	17.60	15.15	5.73	19.94	4.63	5.83
	E	9.63	4.87	30.64	14.70	4.55	20.60	6.94	8.07

Muscle work percentage can effectively reflect the importance the muscle in completion of a certain motor, usually according to the ratio of one muscle iEMG to the whole tested muscle iEMG (LIU Cun Zhong,2010[14];LIU Min et al .,2019[15]). Table 1-3 are the integral electromyography ratio of each muscle in the two stages (flexion and extension) from the left leg of Yu Jing, Wang Beixing and Zhang Hong in straight supporting, respectively. From these three tables, we can see two obvious features: one is, if the first four of iEMG ratio are regarded as the main work muscle, no matter flexion or extension phase, there were very stable. For Wang Beixing and Zhang Hong ,TA,VM,VL and BF were the main work muscle in F and E phase ,while SEM replaced BF in extension for YuJing. Second, the floating of each muscle iEMG ration in all athletes is small between three strides.

Table 4 iEMG of each muscle in straight from Yu Jing right leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	20.43	3.53	20.24	18.66	18.60	5.17	9.46	3.91
	E	7.78	13.11	24.78	17.44	18.44	5.48	6.92	6.05
2step	F	22.08	3.52	20.14	17.68	17.77	5.45	8.80	4.57
	E	10.33	10.87	25.23	20.85	18.09	2.30	7.37	4.95
3step	F	22.04	3.73	21.01	18.21	12.79	6.44	12.70	3.08
	E	8.02	10.76	18.92	21.20	19.28	4.31	10.44	7.07

Table 5 iEMG of each muscle in straight from Wang Bei-xing right leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	24.34	3.11	29.52	14.30	10.53	7.19	8.16	2.85
	E	3.26	17.65	27.76	19.88	14.74	3.94	9.08	3.68
2step	F	24.49	3.85	27.70	15.16	10.67	6.67	8.40	3.06
	E	3.72	16.62	26.32	18.47	17.23	4.23	8.57	4.85
3step	F	25.51	3.59	23.97	16.02	10.57	7.91	8.73	3.70
	E	4.37	13.96	28.26	20.02	15.90	3.45	9.00	5.05

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Table 6 iEMG of each muscle in straight from Zhang Hong right leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	17.71	2.41	28.78	12.55	22.99	5.17	6.89	3.51
	E	10.66	5.82	32.73	20.47	13.84	3.99	6.47	6.02
2step	F	18.65	2.62	21.38	13.46	27.08	6.53	6.94	3.34
	E	8.76	8.9	32.35	21.03	13.23	4.09	7.51	7.14
3step	F	20.44	2.88	22.76	12.73	22.7	6.46	8.65	3.39
	E	7.05	5.86	34.4	21.64	15.22	4.63	5.48	5.71

Table 4-6 shows the work of each muscle form right leg in the straight of three athletes. For Yu Jing, TA, VL, VM and RF were the main working groups during the F phase, while the E phase were VL, VM, RF and GL. For Wang Beixing, the main work muscles during F phase were TA, VL, VM and RF, GL, VL, VM and RF were for F phase. For Zhang Hong's, the main work muscles during F and E phase were consistent, there were TA, VL, VM and RF. So, the common trend of the three athletes was, TA, VL, VM and RF were the main workgroups in the phase of flexion, VL, VM, RF were the main workgroups in the process of extension. The difference was Zhang Hong depended more on TA, while YuJing and Wang Beixing relayed more on GL in F phase.

3.2 RMS

Table 7 RMS of each muscle in straight from Yu Jing left leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	27	11	13	27	19	25	12	26
	E	19	21	25	45	25	34	26	49
2step	F	26	9	13	32	16	26	13	29
	E	20	36	27	40	20	39	21	42
3step	F	34	10	17	39	14	32	5	21
	E	20	23	25	41	21	30	25	47
1step	F	29	10	14	33	16	28	10	25
	E	20	27	25	42	22	34	25	46

Table 8 RMS of each muscle in straight from Wang Bei-xing left leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	28	6	29	21	15	19	12	9
	E	18	19	32	27	22	30	17	16
2step	F	30	8	30	22	15	20	12	11
	E	18	21	36	24	19	33	16	17
3step	F	24	6	29	22	18	22	13	9
	E	14	25	34	24	23	30	30	16
1step	F	27	7	29	22	16	20	13	10
	E	17	22	34	25	21	31	21	16

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Table 9 RMS of each muscle in straight from Zhang Hong left leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	37	12	11	21	16	17	6	26
	E	18	29	18	25	17	21	7	41
2step	F	31	15	10	17	16	15	6	21
	E	16	32	20	21	17	21	8	29
3step	F	36	15	11	22	15	15	5	27
	E	15	25	21	20	14	14	9	42
1step	F	33	13	11	20	16	16	6	25
	E	16	28	20	22	16	19	8	37

The value of RMS has a clear physical meaning (De Luca CJ,1997)[16], representing the level of recruitment, synchronization and activation of motor units (Thiago Y F,2010[17];SUN Ke,2019)[18]. Therefore, this indicator was used to reflect excitation intensity in this study. Yang(1984) [19]and Clarys(2000)[20] have proposed that it is not appropriate to use static MVC electromyography to normalize muscle electromyography in exercise, and recommended that use the peak value of electromyography in exercise to normalize is more reasonable. Therefore, we used the EMG peaks of each muscle in the whole experiment to normalized them separately (R.W.de Boer ,1987)[21]. Table 7-9 were the normalized root mean square electromyography of left leg from Yu Jing, Wang Beixing and Zhang Hong in straight, respectively. The changes of the activation between flexion and extension of each muscle in three athletes had a high regularity: the excitation intensity of TA was greater in F phase ,while others were more in E phase. It reflected that TA is contracted greater in landing and undertaking the center of body mass, and smaller in push-off phase, while other muscles were contracted more strongly in E phase.

Table 10 RMS of each muscle in straight from Yu Jing right leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	39	10	21	32	26	13	21	19
	E	18	38	28	37	39	11	18	35
2step	F	40	9	18	27	27	9	17	21
	E	23	32	29	40	34	5	18	34
3step	F	40	10	20	29	25	11	22	14
	E	19	32	23	39	33	9	23	37
1step	F	40	9	19	29	26	11	20	18
	E	20	34	27	39	35	8	20	35

Table 11 RMS of each muscle in straight from Wang Bei-xing right leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	32	8	36	25	21	18	21	15
	E	8	34	42	41	37	13	29	25
2step	F	30	8	33	25	21	17	21	15
	E	9	30	36	35	37	12	23	27
3step	F	31	7	27	26	20	19	20	18
	E	9	30	38	38	36	10	24	29
1step	F	31	8	32	25	21	18	21	16
	E	9	32	39	38	36	12	25	27

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Table 10-12 were the excitation intensity of right leg. When to YuJing and Wang beixing, TA and BF were more excited in F phase while others were on the contrary. Compared the changes of each muscle excitation intensity between right and left leg, we could found there were consistent except for BF. For ZhangHong, TA,RF ,BF and SEM were more excited in F phase , and others were more in E phase. Therefore, we can conclude that when gliding with right leg, TA and BF were more excited in F phase, while GM,VL,VM, and GL were more in push-off phase, but there was no fixed trend in SEM and RF among the three players. The biggest difference from the left leg was that the change of BF excitation intensity in flexion and extension is exactly opposite.

Table 12 RMS of each muscle in straight from Zhang Hong right leg(%)

		TA	GL	VM	VL	RF	BF	SEM	GM
1step	F	39	9	28	26	22	12	24	19
	E	17	17	26	35	11	7	18	28
2step	F	35	13	19	25	23	13	25	17
	E	16	22	26	37	10	7	24	34
3step	F	37	9	19	23	19	12	26	16
	E	13	22	28	39	12	8	18	32
1step	F	37	10	22	25	21	12	25	17
	E	15	20	27	37	11	8	20	31

3.3 Activation modality

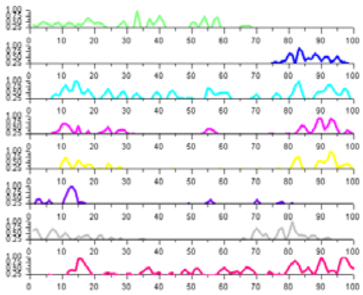

Fig 1 Yu Jing left leg normalize sEMG

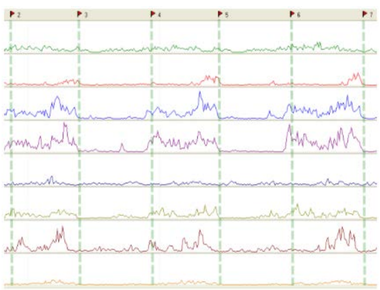

Fig 2 Yu Jing left leg RMS sEMS 2-3,4-5 and 6-7 were three supporting phases

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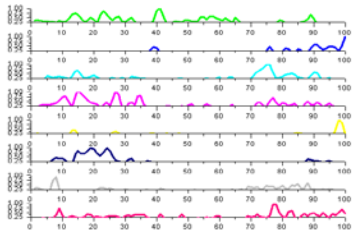

Fig 3 Zhang Hong left leg normalize sEMG

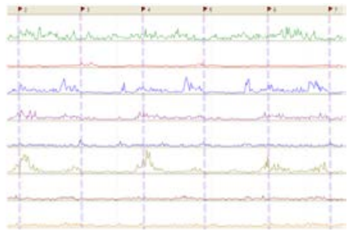

Fig 4 Zhang Hong left leg RMS sEMS 2-3,4-5 and 6-7 were three supporting phases

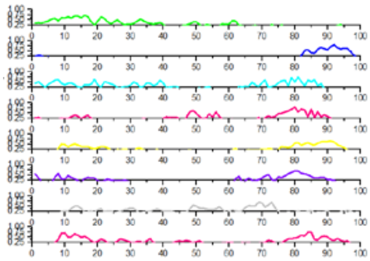

Fig 5 Wang Bei-xing left leg normalize sEMG

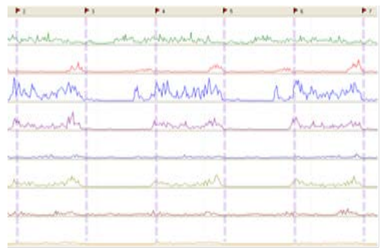

Fig 6 Wang Bei-xing left leg RMS sEMS 2-3,4-5 and 6-7 were three supporting phases

Almost all action involved the participation of different muscles, there are prime mover, antagonist and synergist, which must be coordinated to make the skill complete accurately, smoothly and economically. Physiologically, this process is actually alternating excitation and inhibition of each muscle under the central nervous system at the precise time and space, that is, the onset and offset of each muscle. In some exercise, even if we use the same muscle, if the order of muscle onset is different, will show different motor skill or different motor efficiency. In sports practice, we often see that the technique of elite level athletes are not only smooth, but also rich rhythm and power, while beginners appear tense and awkward, stiff and redundant. This shows that the coordination and activation modality had decisive effect on the efficiency of motor. Therefore, in recent years, a large number of researchers have studied muscle activation modality, such as YU Zhi gang et al .(2008)[22] and WU Xiao-nan et al .(2018) [23].

It is also of great value to study the muscle activation modality of excellent speed

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skater gliding on ice. On the one hand, we can explore the problems of one athlete's technical movement from a deeper level, on the other hand, we can choose and design the strength training interventions more scientifically. In the following figure, the signal from top to bottom are TA, GL, VM, VL, RF, BF, SEM and GM.

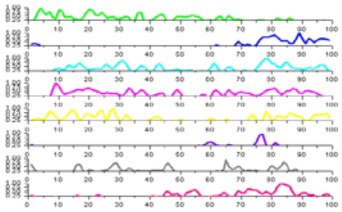

Fig 7 Yu Jing right leg normalize sEMG

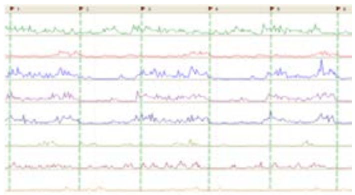

Fig 8 Yu Jing right leg RMS sEMS 1-2,3-4 and 5-6 were three supporting phases

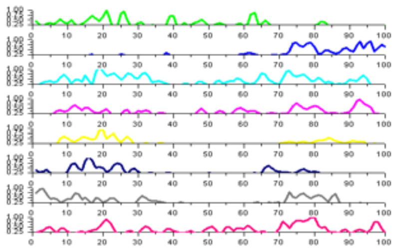

Fig 9 Zhang Hong right leg normalize sEMG

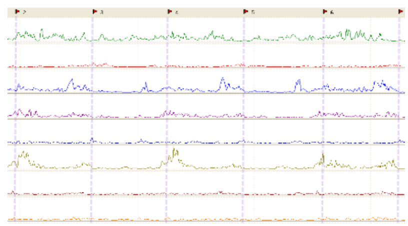

Fig 10 Zhang Hong right leg RMS sEMS 2-3,4-5 and 6-7 were three supporting phases

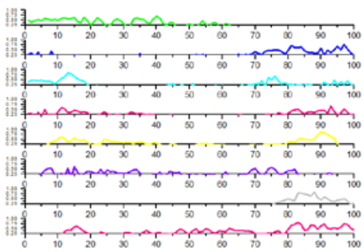

Fig 11 Wang Bei-xing right leg normalize sEMG

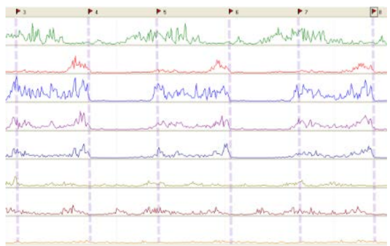

Fig 12 Wang Bei-xing right leg RMS sEMS 3-4,5-6 and 7-8 were three supporting phases

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From the normalize electromyography sEMG and RMS sEMS of the three athletes, it can be seen that the onset of TA and SEM were first when landing, then the VM and VL, the GL was final; the offset of TA was first when push-off, then SEM, and finally the GL, VM and VL when leaving the ice.

3.4 Skill stability analysis

The stability of the technique is an important index to evaluate the athlete's motor quality, especially for the single repeated action of the racing sports. Deformation of technique and decrease of mechanics effectiveness are the important factors that restrict the improvement of competition performance. The correlation of EMG amplitude reflects the stability of skill in cyclic action completion. If each muscle has a high correlation in the process of completing same actions, it can be considered that the action composition has a high convergence at the physiological level. So, we'll look at the correlation between EMG amplitude to evaluate athletes motor stability.

Table 13 correlation coefficients of each muscle of the left leg with individual model (%)

	YU Jing	Wang Bei-xing	ZhangHong
TA	71.07	74.78	71.86
GL	87.98	92.40	79.53
VM	83.72	75.41	90.95
VL	73.71	82.63	80.49
RF	71.88	75.41	71.29
BF	74.33	79.59	85.20
SEM	81.22	77.42	75.07
GM	84.11	78.63	66.48

Table 13 is the mean correlation coefficients of each muscle from the left leg of Yu Jing, Wang Beixing and Zhang Hong with individual mode in the straight. According to the EMG characteristics, sample size and correlation function, we proposed that the correlation coefficient above 0.7 was high correlation and 0.5-0.7 was moderate correlation. From Table 13, we can see that the EMG of each muscle of the three athletes is highly correlated with the individual model (except the gluteus maximus of Zhang Hong). Therefore, we can say that the three athletes in the process of repeated action, each muscle EMG changes have a higher stability, think that the three outstanding athletes left leg motor was very stable.

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Table 14 correlation coefficients of each muscle of the right leg with individual model(%)

	YU Jing	Wang Bei-xing	ZhangHong
TA	77.49	81.00	73.12
GL	87.50	94.38	79.06
VM	78.61	73.73	76.58
VL	80.92	82.96	73.32
RF	78.29	82.64	83.53
BF	79.01	83.68	75.03
SEM	77.49	81.00	73.12
GM	87.50	94.38	79.06

Table 14 shows the correlation coefficients of each single step of the right leg of Yu Jing, Wang Beixing and Zhang Hongzhi Road with their individual model. It can be seen from the table that the athletes reach a high correlation. Therefore, we believe that the three athletes’ right leg technique is very stable.

4. Dicussion

From the muscle work percentage above, we know that no matter right or left leg, the main work muscles between three athletes in the process of F phase and E phase were consistent. TA, VM, VL and BF were the main work muscle in F phase for left leg , while TA, VM, VL and RF were for right leg. In order to reduce the friction during the landing phase, the athletes will keep the dorsiflexion of ankle with the rear end of the blade to land first, and then transition to the whole blade, TA is in a state of continuous contraction in this process. After landing, there is a process of undertaking body center of mass on the left (right) leg and gliding toward the left (right) side, then the body center of mass move from the left (right) lateral to the medial side, ready to plosive propulsion the ice. In this process, the knee and ankle angles gradually decrease, and then maintained a relative stable angle. Because the blade skate is tiny and the athlete is in high speed gliding, the TA muscle is still actively involved in the work to maintain the stability of the ankle, as the instability of ankle will lead to the decrease of the force transfer (BEHM,D.G ,2002;ANDERSON K,2004) [24-25].So, even if the ankle does not perform dorsiflexion action, the anterior tibial muscle still has a large potential activity after landing. In addition, the shift of body center mass will inevitably lead to heavy load of the VM and VL, and the high proportion work was done by BF to maintain the stability of the knee.

Therefore, we can see the main work muscles in the whole support process are concentrated on the TA and the quadriceps, suggesting that they should be attached more attention in daily strength training. However, although the main work groups in flexion and extension are similar, the different technique indicate that there are some differences in their working way, which should be got more value in strength training. First of all, for TA, it belongs to the centripetal contraction during the ankle dorsiflexion in off-ice, after landing is mainly in isometric contraction to maintain the stability of the ankle. Secondly, VM and VL were mainly passive eccentric contraction in F phase, while the E phase was mainly concentric contraction to provide power for the sprint. Finally, for BF and SEM were mainly concentric contraction in F phase to maintain the stability of the knee, and the E phase is still concentric contraction to extend the hip , which provides power for the sprint. Therefore, we should not only train specific muscles, but also design and choose effective training methods according to their working characteristics in the technique process. In addition, the main work muscles of speed skating have significant characteristics compared with the running events. You know, sprints' power was come from the ischiocrural and GM, nor from TA. The reason for this difference is that the track events belong to the stable supporting, the athletes push back to the ground, while the speed skating is the sliding supporting, the athletes pushing perpendicular to the advanced orientation; the second is the track events is the surface support, belongs to the rolling force process, and the speed skating is the line support, belongs to the lever force, so the skates this a special equipment which will recruit different power from lower limb .

From the analysis of muscle activation intensity, we know that the changes of the activation levels of each muscle in F and E phase between three athletes was high regularity, regardless of the left or the right leg. For left leg, TA was activated more in F phase and others were opposite. For right leg, TA and BF was activated more in F phase and others were opposite. The normalize EMG of the same muscle has good comparability, and the activation level in flexion and extension phase can reflect the activation intensity. Among the three athletes, the electromyography showed a consistent trend between flexion and extension, which reflected the characteristics of the technique.

From the analysis of muscle activation modality, we know that the root mean square electromyography shows a significant rhythm, and the EMG amplitude has a high correlation, indicating that the elite athletes' skill is stable when in the same motor, the activation order of each muscle has a strong regularity. Although there were litter differences in the order of activation of each muscle between three athletes, the overall trend was that TA was activated first, followed by VM,VL and BF. TA was inactivated first, VM, VL and GL were inactivated at the time of off-ice. We can get three enlightenment form this. First of all, elite level athletes complete the same motor shows rhythm which indicate a perfective skill. Second, the sustained contraction of TA during the whole supporting phase reflect that its special strength is very important for speed skating. At last, the iEMG of VM, VL and BF reached peak at the same time in push-off, which indicated that the mechanism of main work muscle in elite athletes belong to collective explosive pushing, which is beneficial to provide more concentrated and effective power for skating.

we also see that there are two common points between the left and right legs of the three athletes: one is that Yu Jing and Wang Beixing have strong signal in GL at the later stage of supporting but Zhang Hong did not. As you know, the GL is an important muscle for sprint and jumping events, because its main function is ankle dorsiflexion, which can transfer strength effectively and increase the power, so the

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fasted and powerful sports need play great importance on the GL strength training. Under the conventional skates, blade firmly fixed to the bottom of the boot, in order to avoid scratching the ice, athlete need suppress plantar flexion throughout the supporting period. When Klapskates appear, it permits the shoe to rotate on a hinge relative to the blade. This allows plantar flexion with the blade remaining flat, gliding on the ice.[26-27]

(Van Ingen schenau,G.J,1996).Although the reasons for the significant increase in the performance by Klapskates are still controversial (increasing the forward distance of body center mass, increasing the efficient of pushing, releasing the extension amplitude of knee joint, increasing the power and reducing ice resistance), ankle extension at the end of the pushing is undoubtedly a reality, and the GL, the main muscle of ankle extension, should be activated to participate in the work during this phase. However, both the left and right legs, Zhang Hong's GL was inactivated throughout the supporting period, which obviously ran counter to the above analysis. Causes of this phenomenon may be related to its initial specificity —— short track speed skating. The shoes are still tightly connected to the blade which limited plantar flexion. In addition, the typical technical characteristics of short track speed skating are gliding on curve, the technical requirements slightly lower in pushing but highly in controlling skate, which must require the strong intervention of the TA. Therefore, it is suggested that the training of GL should be reinforce in the future when short-track speed skater switch to long track speed skater, so as to adapt and utilize the advantages of the Klapskates and provide new possibilities for the growth of sports performance.

5. Conclusions

TA and quadriceps muscle are the main work muscles; BF and SEM play an important role in keep the stability of the knee joint during the body center of mass transition, and GL is work at the end of the push-off phase. The excitation intensity of TA and BF is more in flexion phase, while others are more in extension phase. Elite athletes’ muscle activation modality is regular in the same motor skill. The onset of TA is first, followed by the VM, VL and BF; The offset of TA is first, and then the offset of VM, VL and GL at the time of off-ice. Elite athletes’ motor are very stable.It is suggested that in the practice of special training, the main work muscles and their special work way should be trained in order to improve the pertinence and effectiveness to the strength training; Put more punch to the GL strength training when short track speed skaters turn to speed skater.

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