

新しいクラウチングスタイル・スタートの生物力学的研究

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Biomechanical Study On A New Crouching Start (Chen's Start)

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スタートは、陸上競技の短距離走種目にとっては非常に重要な一部分で、成績に大きく影響を与えるものである。今迄、短距離走の技術に関する研究では、スタートに関するものがかかなり多く、とくにスタート時の銃声に対する反応の速さ、スターティング・ブロックに加える蹴りの強さ、また、前後の足の位置とスタート時におけるそれぞれの足の蹴りの強さ、動作時間の速さなどの比較研究や、スタートの直後の歩幅の問題、前傾角度の問題、加速の問題、胴体及び四肢の位置の問題などが、重要な課題とされて来た。

本研究は陸上競技のスタートを基本から変え、より合理的なスタートを可能にさせるため、工夫したものである。現在使用されているスタートは一般的に「用意」の号令で腰を高く上げて、両足で軽くスターティング・ブロックを蹴り、号砲(銃声)に従い走り出すものである。

本研究が用いた新しいスタートの方法は、「用意」の号令時から、スタートの号砲が鳴るまでの間に、前の足の蹴りに対し、後の足が引くことによって、前の足のキックの水平方向の力を強化し、更に、両手への「用意」時の体重負担を大きく軽減させ、従来のスタートよりも素速く、低い前傾姿勢でスタートすることが出来るように改良されたものである。

ABSTRACT

This is the biomechanical study on a new crouching start (Chen's start). Eight university decathlon athletes were asked to use the two different kinds of start (conventional and Chen's). Studies were done by recording the EMGs of the lower extremities' muscles and the forces both during "set" position and at the time of start, by filming from the "set" position to about three steps after the sound of the starting gun, and by timing and recording performances of the 30 meters dash with three trials for each start. The new start reduced performance time by 0.029 second. Pressure on hands were reduced from 27.50 ± 2.87 kg in the conventional start to 21.79 ± 2.78 kg while using the new start ($p < 0.01$). The peak horizontal force in the front leg was increased in using the new start, from 78.55 ± 9.16 kg for the conventional start to 86.66 ± 10.94 kg

($p < 0.02$) for Chen's start. EMGs appeared during the time of "on your mark" and "set" position were changed both in pattern and in amplitude. In using the new start, the thrust force of the pre-tensed pulling rear leg in the "set" position were increased, the Length of the first step was greater and the angles of forward inclination of the body were lowered for the first few steps.

Key Words : crouching start, "set" position, force, rear leg.

INTRODUCTION

It is well known that a good start in sprint events can make a major contribution to performances (8. 9.) .

Studies have employed biomechanical parameters to examine the mechanism of the sprinter's start, and most of these studies have been concerned mainly with the reaction at the start and the forces exerted by the thrusting of the sprinter's legs against the starting block when using different foot spaces (7. 8. 10.) . Many studies have stressed on the examination of the runner's reaction time and the movement time at the start, after the gun is fired (7) .

For this study, a new modified crouching start (Chen's Start) was designed for sprint' s events.

This start largely differed from the conventional one as regards the position of the rear leg. The new start follows the conventional one in placing both feet on the starting blocks, but during the "set" position, the front leg thrusts while the rear leg pulls isometrically, instead of both legs pushing at the same time, as in the conventional start. This allow the rear leg to be released vigorously at the sound of the gun.

METHOD

Equipments : The newly designed starting block is shown below. The rear block stand

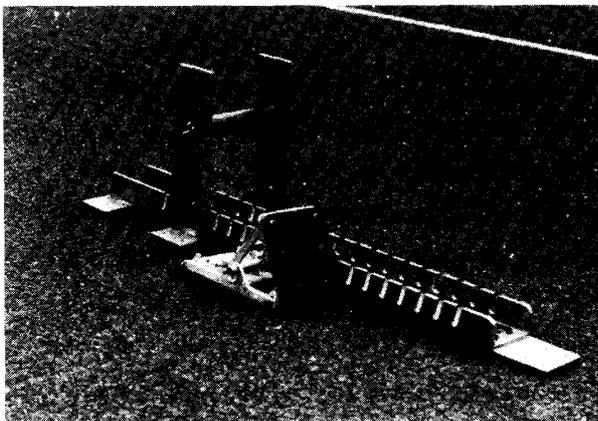


Fig.1 Chen's starting block.

out at right angles to the shank, and the arms of rear block have a runway to allow the

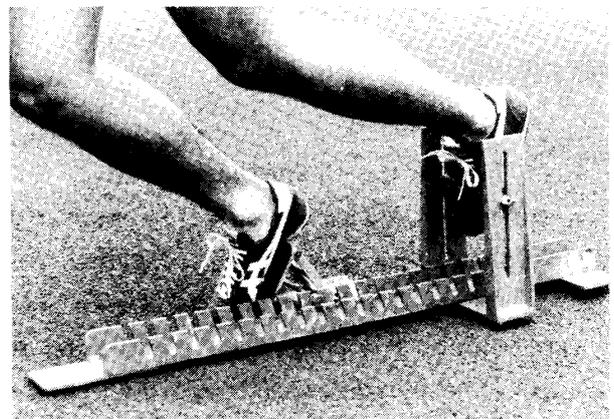


Fig.2 Sprinter's legs in the Chen's starting block at the time of "set"position.

sliding of rear block to adjust the height of the pulling leg. The Adjustment of foot space is made by moving both blocks. A roller covered with rubber was fixed on the rear block, allowing the back of the pulling leg to move out from it quickly and with tension.

Subjects: Eight university decathlon athletes, 19-22 years of age were subjects. They had all trained regularly for several years and had mastered the conventional start already. Measurements taken included EMGs, forces, angles and positions, reaction time, movement time and performance time for 30 meters dash.

Table 1 Characteristics of subjects.

Subjects	Age (yl)	Ht (cm)	Wt (kg)	100 m time (sec.)	Front leg
1	22	175.0	66.6	10.9	Left
2	21	179.0	73.0	11.2	Left
3	19	170.0	62.5	11.3	Left
4	22	174.0	68.5	10.7	Left
5	21	169.0	71.0	11.0	Right
6	22	171.5	61.0	11.4	Right
7	21	179.0	72.0	11.2	Right
8	21	173.0	69.5	11.2	Right
<i>M</i>	21.1	173.81	68.01	11.24	
<i>SD</i>	0.9	3.52	4.09	0.42	

EMGs: The mechanism of muscle contraction during "on your mark" and "set" positions were studied by recording of action potential from the muscles of both legs. Muscles concerned were the Rectus femoris, Tibialis anterior, Biceps femoris, and Gastrocnemius in the lower extremities.

Forces: Forces exerted by the thrusting leg in the "set" position, untill the runner broke contact with his Leg from the front block, were measured by a force platform (Kislar). The force platforms were placed on the Track with a specially devised aluminium cover on which the Starting blocks were firmly fixed. Forces along the vertical and horizontal directions of both legs were measured.

Performance: Reaction time, movement time, and performance time in the 30 meters dash were measured by a time counter which was triggered automatically by the starting gun, and was stopped by a signal from the photo cell at the finish line.

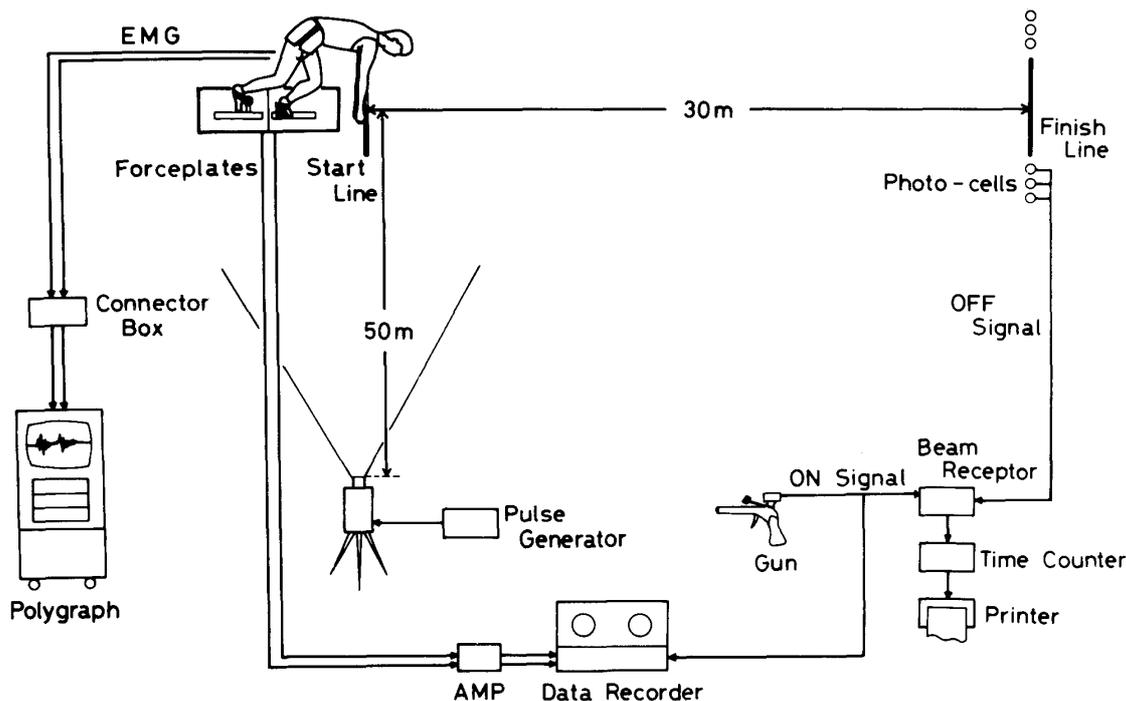


Fig.3 Block diagram and the Set-up of this experiment.

Table 2 The peak forces at start for two different starts.

Subjects	Conventional start								Chen's start							
	Front leg				Rear leg				Front leg				Rear leg			
	Horizontal (backward)		Vertical		Horizontal (backward)		Vertical		Horizontal (backward)		Vertical		Horizontal (forward)		Vertical	
1	83.44		79.19		19.42		32.27		78.91		82.88		16.81		4.85	
	80.04	81.05	80.37	79.45	20.14	21.98	29.04	34.59	92.07	85.31	81.55	82.88	19.14	18.52	0.76	2.37
	79.67		78.80		36.37		42.46		84.94		84.21		19.29		1.50	
2	53.59		73.71		38.48		61.65		78.91		74.46		13.78		0.33	
	63.81	60.53	71.35	72.14	35.16	35.82	59.44	60.86	79.46	77.09	78.01	76.38	15.05	14.30	0.73	0.85
	64.19		71.35		33.81		61.48		72.89		76.88		14.05		1.50	
3	78.54		78.80		6.35		17.49		77.82		82.44		15.15		0.70	
	76.25	75.89	77.63	78.28	11.15	7.95	27.17	20.32	76.72	75.44	80.22	77.53	13.41	13.90	0.90	1.45
	72.87		78.41		6.35		16.30		71.79		69.93		13.13		2.76	
4	81.18		81.55		22.78		37.19		94.81		89.53		9.92		7.91	
	80.80	80.80	79.19	80.24	29.73	26.69	61.65	53.61	84.94	89.69	84.21	84.51	16.35	14.05	5.52	4.70
	80.42		79.98		27.57		61.99		89.33		79.78		15.89		0.66	
5	83.82		79.19		27.69		58.01		103.57		89.97		22.50		2.19	
	78.91	80.67	78.41	79.06	29.25	28.49	60.12	59.36	97.00	99.74	85.54	85.69	20.21	21.34	0	0.73
	79.29		79.59		28.53		59.95		98.64		81.55		21.31		0	
6	72.12		78.40		17.14		38.55		77.82		70.92		21.68		0	
	75.89	73.38	76.84	77.36	17.98	19.54	37.70	42.40	71.79	74.17	70.92	70.48	19.38	20.70	0	0
	72.12		76.84		23.50		50.95		72.89		69.59		21.03		0	
7	93.64		79.59		8.27		18.68		105.20		84.66		16.72		0	
	97.04	95.65	79.19	79.85	5.75	7.15	9.00	14.72	102.48	106.67	85.98	84.95	18.09	18.12	0	0.31
	96.28		80.76		7.43		16.47		112.34		84.21		19.56		0.93	
8	75.89		78.80		13.91		30.91		78.37		82.88		16.53		3.69	
	78.53	80.42	78.41	80.86	13.91	13.75	39.23	34.36	89.33	85.13	82.88	82.59	15.61	16.62	5.88	4.45
	86.84		85.37		13.43		32.95		87.68		82.00		17.73		3.79	
<i>M</i> ± <i>SD</i>	78.55	±9.16	78.41	±2.58	20.17	±9.49	40.03	±16.16	86.66*	±10.94	80.62	±4.99	17.19**	±2.77	1.86**	±1.70

*Significant at .05 level.

**Significant at .001 level.

RESULTS

Peak forces: Analysis of variants in the results showed, first of all, that the new start increased horizontal peak force significantly. The horizontal force at start was 78.55 ± 9.16 .

Table 3 Comparison of pressure on hands (kg) at start between two starts.

Subjects	Conventional start	Chen's start
1	25.39	22.73
2	30.19	20.72
3	22.40	18.84
4	25.62	26.94
5	27.81	22.49
6	24.38	18.62
7	30.18	25.20
8	30.50	19.17
<i>M</i>	27.05	21.79
<i>SD</i>	2.87	2.87*

*Significant at .01 level.

16kg for the conventional one, and 86.66 ± 10.94 kg for the new start.

Pressure on the hands during "set" position was reduced significantly. Values of the pressure on the hands for conventional start was 27.05 ± 2.87 kg, while it was 21.79 ± 2.87 kg for the new start. The peak horizontal forces exerted by the rear leg differed in the direction and magnitude with the two different kinds of start, being in a backward direction with a peak force of 20.71 ± 9.49 kg for the conventional start, and was 17.19 ± 2.77 kg in forward direction for the new start at the time soon before start. There was a small upward directional force from the rear leg in the new start during "set" position due to the pulling action, and this force turned downward as the runner began to move his leg forward after the sound of the gun.

The total peak forces in the conventional start at the time of start from both legs was 118.44kg in a vertical direction, where force

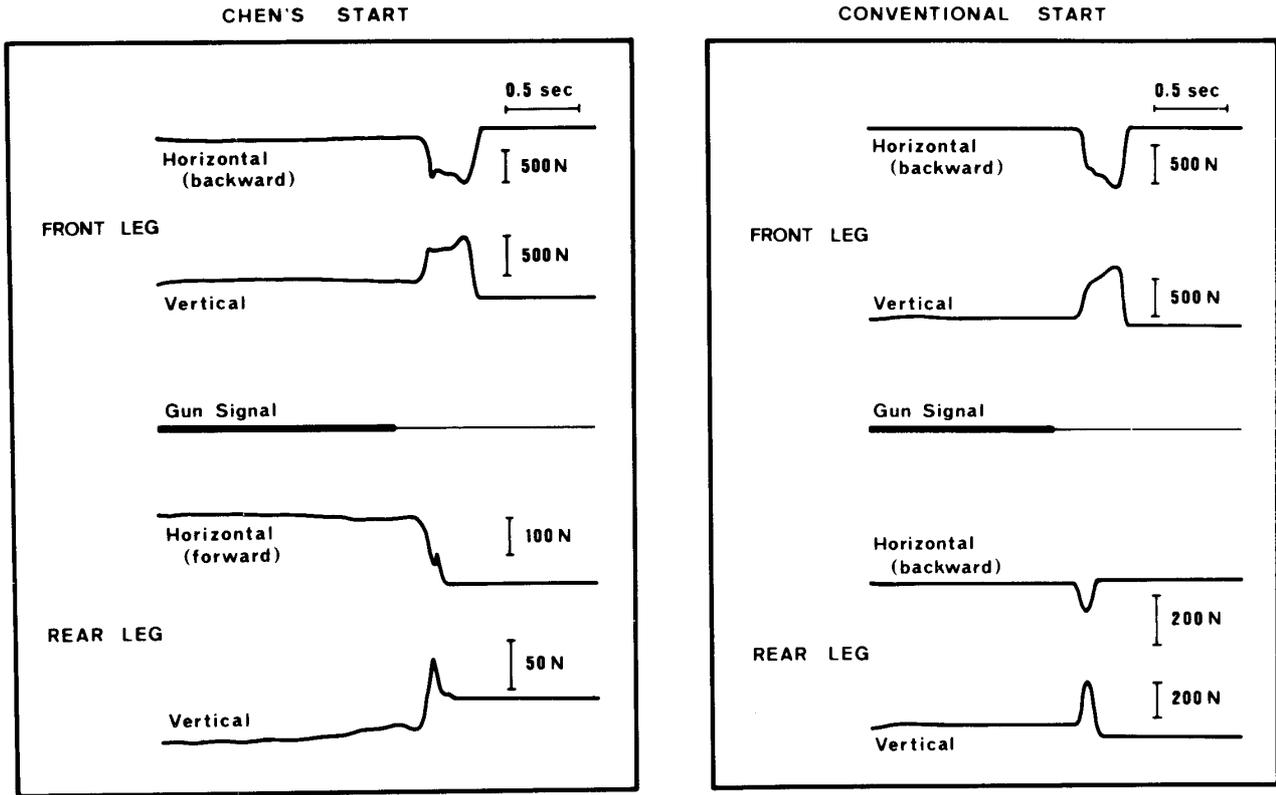


Fig.4 Raw data of the forces during "set" position and at start.

from the rear leg being 40.03kg (33.79%), and total force in a horizontal direction was 98.72kg in which force from the rear leg amounting to 20.17kg (20.43%). In the new

start the total vertical force was 82.48kg, of which the force from the rear leg comprised 1.86kg (2.26%).

The total horizontal peak force in the new start was 103.8kg, force from the rear leg being 19.48kg (17.19%), in a forward direction at start. The significant increase in the front leg's horizontal force at start is one of the most important factors enhancing mechanical efficiency for a good start.

Forms: Analysis of films taken with a high speed cinecamera showed that the two starts manifested different starting profiles during "set" position and when beginning to take the first step after the gun was fired. In the new start the runner raised his hip higher and placed his front leg closer to the starting line than in a conventional start. At the same time, the runner moved his shoulder farther away from the starting line in the new start than he could for the conventional one during "set" position. The angle between the line

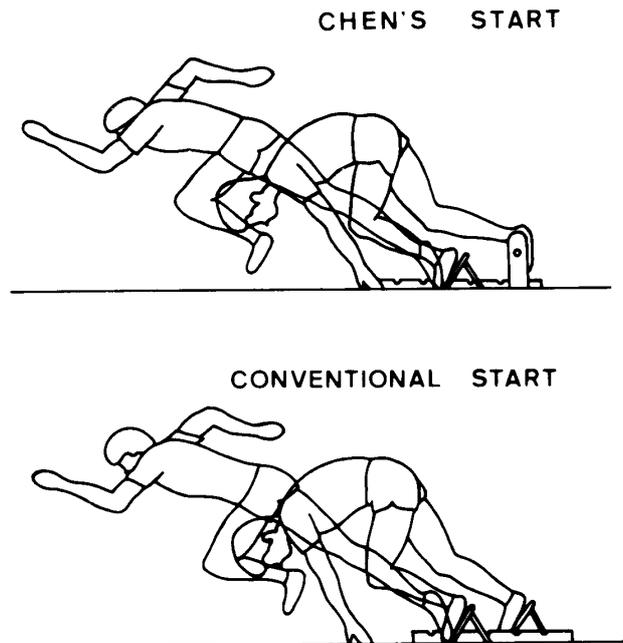


Fig.5 Comparison of forms of Chen's and conventional start.

Table 4 Comparison of 30 m dash time (sec.) between two starts.

Subjects	Conventional start				Chen's start			
	1	2	3	<i>M</i>	1	2	3	<i>M</i>
1	4.38	4.33	4.33	4.35	4.27	4.29	4.27	4.28
2	4.44	4.43	4.45	4.44	4.45	4.32	4.41	4.39
3	4.49	4.52	4.57	4.53	4.54	—	—	4.54
4	4.34	4.46	4.46	4.42	4.45	4.41	4.47	4.44
5	4.47	4.40	4.37	4.41	4.27	4.35	4.42	4.35
6	4.54	4.50	4.52	4.52	4.52	4.51	4.58	4.53
7	4.41	4.33	4.33	4.36	4.25	4.33	4.27	4.28
8	—	4.77	—	4.77	4.71	4.79	4.78	4.78
<i>M</i>				4.475				4.446
<i>SD</i>				0.127				0.150

from the hand and the vertical line down from the acromion of runner's shoulder to the ground was greater in new start, which meant that the runner's upper portion of the body could move forward farther.

The angles from the trunk and the horizontal, and the angle from the front leg and the horizontal Line at the time just before the leg brock contact with the front block were smaller in the new start.

Performace: The time for 30 meters dash was shortened when using the new start. Time for the conventional start was 4.475 ± 0.127 second, and for the new start it was 4.446 ± 0.150 second. Average running time was reduced by 0.029 second, even though the

runner did not have much practice for the new start.

Length of first step: Parameters for a reasonably good sprint start should be that the runner can take a long first step while keeping in a low body profile and move fast. In the new start the first step was lengthened by 5.26cm over the conventional start. This lengthening was partly due to an increase in the horizontal thrust forces from front leg at start.

EMGs: The electromyographic study indicated that while the runner was in the "on your mark" position muscles of Rectus femoris and Tibialis anterior in the front leg worked intensively during the conventional

Table 5 Length (cm) of the first step of the two different starts.

Subjects	Conventional start				Chen's start			
	1	2	3	<i>M</i>	1	2	3	<i>M</i>
1	44.5	40.5	34.4	39.8	57.4	54.4	55.0	55.6
2	54.0	59.1	44.5	52.5	32.0	47.3	49.0	42.8
3	41.5	53.0	44.0	46.2	56.0	—	—	56.0
4	43.5	34.5	37.0	38.3	46.0	45.0	49.5	46.8
5	47.5	48.3	50.8	48.9	47.5	41.1	50.3	46.3
6	56.5	51.0	59.0	55.0	55.0	61.2	40.5	52.2
7	49.0	43.0	42.0	44.7	60.1	47.3	50.5	52.6
8	29.5	29.0	—	29.3	46.5	52.4	35.6	44.8
<i>M</i>				44.39				49.63
<i>SD</i>				7.91				4.75

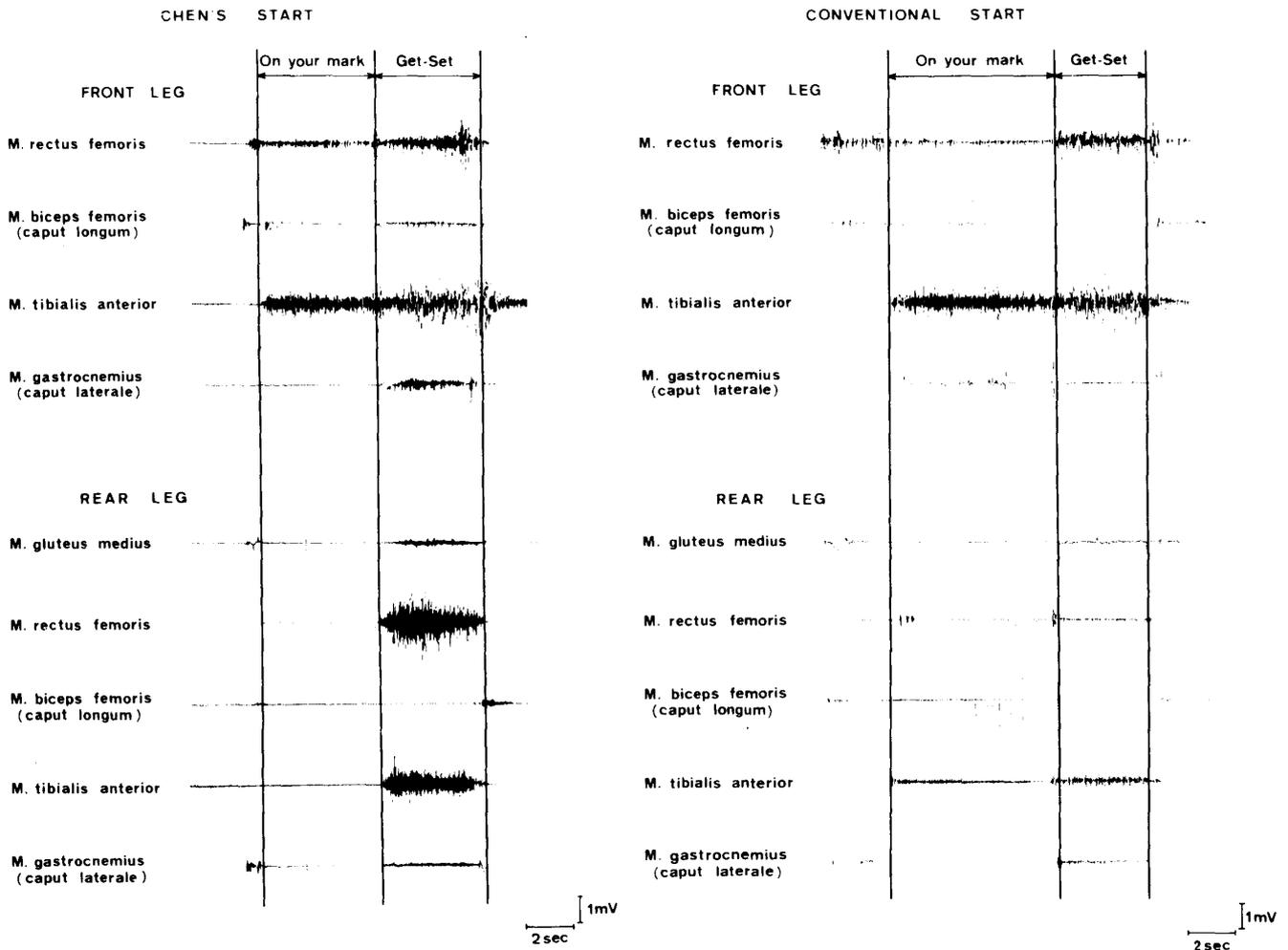


Fig.6 EMGs of the lower extremities muscles during "on your mark" and "set" position in Chen's and conventional start.

start, while in the new start the Tibialis anterior in rear leg showed a moderately low continuous charge in the "on your mark" position. EMGs showed an increasing voltage in all muscles for the "set" position in two starts. The pre-tensed pulling leg in the new start increased discharge from the Rectus femoris and Tibialis anterior muscles in the rear leg, and the pulling action of the rear leg in the new start strengthened the thrusting action of the front leg for "get set".

DISCUSSION

The isometrical contraction of the Rectus

femoris and Tibialis anterior muscles pulled back some of the weight of upper trunk, as a result, reduced the burden of pressure on the hands, allowing the runner to move his hands freely at the start. Strong and effective hand movement gave the thrusting leg a great deal of help in pushing the body away from the block when the gun was heard (4. 10.). The pulling leg retained some tension during the "set" position, which accelerated the vigorous forward drive of the rear leg, and a strongly driving rear leg strengthened the thrusting force of the front leg (1. 2. 3.). These EMGs findings gave us the evidence for believing that the new start had two main advantages for a good start. Firstly, isometric pulling of

the rear leg during the "set" position stored energy for the following driving-out action once the gun was heard, and reduced the weight of the upper trunk on the runner's hands in the "set" position. Secondly, the horizontal force of the front leg was increased by the counter action of pulling rear leg, which also lengthened the first step of start (6. 8.).

Performance time: Time in 30 meters dash was improved by using of the new start. This result confirmed our expectation and hypothesis, that is, a good start is vital in sprint events.

Forces: The new start increased the forces active while the runner was on the starting block, the dorsa of the rear foot was used to pull the body from the rear block isometrically, and this counter action against the push of the front leg significantly strengthened the horizontal thrust force from the "set" position until the time when a runner started to drive forward. This increase of force in the front leg greatly contributed to lengthening the first step, as well as lowering the angle of decline of the starting position. These conditions are importance for a good sprint start. The pulling rear leg in the "set" position provided the means of satisfying requirements.

In the conventional start, the runner used his leg to tap the rear block before driving out, but this action was not found in the new start. The tapping action of the rear leg before driving out did not increase the horizontal force in the front leg and might lead to the considerable delay at the time of start (7).

The pulling leg during "set" position is a reasonable isometric exercise for sprinters to develop thier muscle strength and neuromotor pattern for sprint start.

SUMMARY

In summary, the results of this study do support our hypothesis that a pre-tensed pulling rear leg during "set" position strengthens the thrust, particularly the peak horizontal force in the front leg. It also reduces the amount of pressure on the hands and prevents runners from intentionally breaking away too soon. The new start also has the advantages of being easy to learn and of providing special isometric training of muscle strength for sprinters during start from the view point of neuro motor pattern.

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