EVALUATION OF SPEED CHANGE IN 100 M SPRINT RUNNING

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The purpose of this study was to propose a method to evaluate speed in 100m running with modified exponential equations. The speed changes in 100m sprint race of ninety-six sprinters (62 men and 34 women) were measured with a LAVEG system. The 100m race was divided into the acceleration and deceleration phases based on the maximum speed, and speed were estimated. 1) The exponential equations proposed in this study well estimated the speed change pattern of the 100m on the different record groups. The average errors between the official time and the time estimated were 0.024±0.040s in men and 0.04±0.039 in women. 2) The maximum speed was the most important factor for both men and women sprinters to achieve best performance the race. 3) The men world class sprinters accelerated quickly (large *k*), but reached the maximum speed later than the other sprinters, which resulted in shorter deceleration phase and smaller decreases in speed after reaching the maximum speed.

KEY WORDS: maximum speed, sprint, exponential equation.

INTRODUCTION:

The speed change pattern of 100m sprint running has been investigated by using an exponential equation proposed by Shibukawa(1969). Although the exponential equation could well evaluate the speed change in acceleration phase, it did not describe the speed change in deceleration phase. In order to apply scientific findings on speed change patterns to sprint training for the improvement in 100m sprint performance, it is necessary to properly evaluate the characteristics of sprinters in the acceleration, maximum speed and deceleration phases. The purpose of this study was to propose a method to evaluate the characteristics of speed change pattern for 100m sprinters to explain characteristics of speed change of the different record groups, by using a laser-type speed measurement instrument (LAVEG system) and a modified exponential equation method

METHODS:

We measured speed changes in 100m sprint running during several competitions including the 11th IAAF World Championships in Athletics, 2007 for 96 sprinters (62 men and 32 women) from the audience seats, using a laser-type speed measurement instrument named LAVEG. According to the record level, men and women subjects were divided into world class and Japanese top class (Table 1). The LAVEG system emits laser that is reflected by the subject's trunk and returns. The distance between LAVEG system and the moving subject is calculated at a rate of 50Hz or 100Hz by the time lag between emitted and received lasers over the duration of the collection. Since a numerical differentiation of the distance by time usually results in noisy data, we smoothed the displacement of the sprinter with a Butterworth digital filter cutting off 0.5Hz (Kintaka, 1999), and the speed changes of sprinters were calculated by a numerical differentiation of the displacement. As shown in Figure 1, the 100m race was divided into the acceleration and deceleration phases based on the maximum speed, and the speed change patterns were approximated by the following equations.
We used the exponential equation by Shibukawa (1969) to approximate the speed change pattern in the acceleration phase and the exponential equation by Prendergast (2001) for the deceleration phase.

Acceleration phase: $$V_{a(t)} = A\left(1 - e^{-kt}\right) \qquad (1)$$

where *Va* is the speed in the acceleration phase, *A* is the maximum speed obtained from the LAVEG system, *k* is a coefficient of acceleration, *t* is the time elapsed from start, and *e* is the base of natural logarithms.

Deceleration phase: $$V_{d(t)} = A + F(1 - e^{l(t-t_{\max})}) \quad (2)$$

where *Vd* is the speed in the deceleration phase, *F* is decreased speed in the deceleration phase, *ℓ* is a coefficient of deceleration, t_{max} is the time of the maximum speed. *A* and *k* of equation (1) and *F* and *ℓ* of equation (2) were calculated by a least square method from the speed data of acceleration and deceleration.

RESULTS AND DISCUSSION:

Figure 2 shows an example of speed change pattern of a male sprinter whose record was 10.48s. The approximated speed change was very close to the speed change obtained with the LAVEG system, as difficult to distinguish them. Figure 3 shows relationship between the official record and the time estimated by the approximation model(r=0.97, p<0.01). The average errors between the official record and the time estimated were 0.024±0.040s for men and 0.04±0.039s for women.

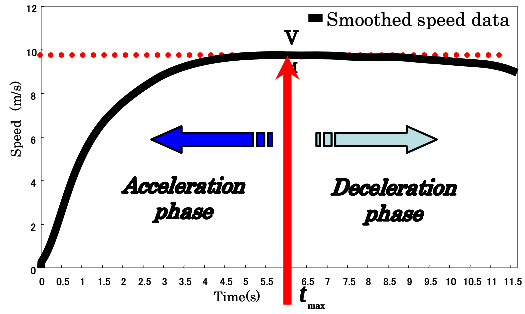

Figure 1 Two phases in the 100 meter in this study(V_M=maximum speed,t_{max}=time at maximum speed)

Table 2 shows correlation coefficients between parameters used in the equations. There was a high positive correlation between the maximum speed and *A* (r=0.99, p<0.01), in all men subjects that the records of the 100m sprint were strongly influenced by the maximum speed during the 100m sprint. A large *k* meant that the acceleration was rapid, and a large *F* indicated a large speed decrease. A large *ℓ* meant that the deceleration was rapid. For all men, there was a negative correlation between *F* and *ℓ* (r=-0.56, p<0.01) and negative correlations between the maximum speed time and *k* (r=-0.39, p<0.01), *ℓ* and *k* (r=-0.43, p<0.01). Therefore, sprinters that rapidly accelerated showed a pattern in which the speed quickly decreased after reaching its maximum. On the other hand, sprinters that moderately accelerated showed a parabolic-shaped velocity pattern. They took longer time to reach the maximum speed, and then decelerated rapidly with time.

Table 1 Grouping of the subjects by the record level

	Group name	N	analyzed record(s)	Max(s)	Min(s)
Men	World class	9	10.18 ± 0.21	9.85	10.44
	Japanese top class	3	10.66 ± 0.24	10.14	11.04
Women	World class	1	11.24 ± 0.11	11.08	11.5
	Japanese top class	1	11.91 ± 0.11	11.71	12.06

For the men world class group, there were significant positive correlation between the record and *ℓ* (r=0.48, p<0.05) and negative correlation between *A* and *k* (r=-0.63, p<0.01). As for the faster sprinters in the men world class, the acceleration was a little slow, but because of the longer acceleration phase, their maximum speed was higher. There was a negative correlation between *A* and *k* in all groups. In addition, a negative correlation was seen between the record and *ℓ* (r=-0.38, p<0.05) in all women subjects. The speed change pattern in faster women was convex with a higher maximum speed and moderate acceleration and deceleration of speed. For women, the maximum speed has a positive effect on their performance.

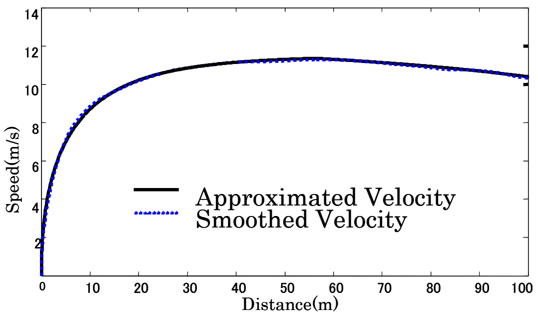

Figure 2 Speed curve during the 100m race for a male sprinter(10.48s).

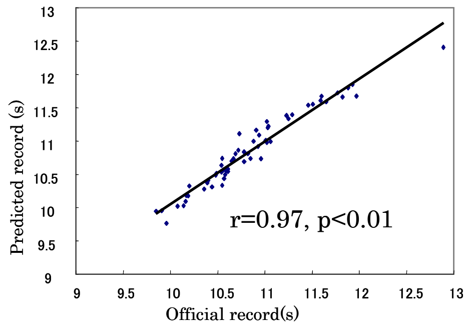

Figure 3 relationship between official record and predicted record in all men subjects

Table 2 Correlation coefficients between parameters

All men subjects

	①	②	③	④	⑤	⑥	⑦
①Record	1						
②Time at Maximum Velocity	−0.23	1					
③Maximum Velocity	-0.97^{**}	0.24	1				
④A	-0.95^{**}	0.20	0.99^{**}	1			
⑤k	-0.28^{*}	-0.39^{**}	0.18	0.10	1		
⑥F	−0.22	0.16	0.20	0.16	0.18	1	
⑦ℓ	0.03	0.18	−0.03	0.02	-0.43^{**}	-0.56^{**}	1

Men world class

	①	②	③	④	⑤	⑥	⑦
①Record	1						
②Time at Maximum Velocity	−0.27	1					
③Maximum Velocity	-0.86^{**}	0.4	1				
④A	-0.77^{**}	0.2	0.92^{**}	1			
⑤k	0.14	0.07	−0.31	-0.63^{**}	1		
⑥F	−0.45	0.11	0.24	0.07	0.34	1	
⑦ℓ	0.48^{*}	−0.12	−0.35	−0.1	-0.58^{**}	-0.76^{**}	1

All women subjects

	①	②	③	④	⑤	⑥	⑦
①Record	1						
②Time at Maximum Velocity	0.31	1					
③Maximum Velocity	-0.96^{**}	−0.35	1				
④A	-0.92^{**}	-0.42^{*}	0.99^{**}	1			
⑤k	0.10	0.10	−0.27	-0.39^{*}	1		
⑥F	0.22	0.25	−0.15	−0.14	−0.19	1	
⑦ℓ	-0.38^{*}	−0.18	0.35^{*}	0.37^{*}	−0.13	-0.49^{**}	1

Women world class

	①	②	③	④	⑤	⑥	⑦
①Record	1						
②Time at Maximum Velocity	−0.08	1					
③Maximum Velocity	-0.76^{**}	0.06	1				
④A	-0.63^{**}	−0.16	0.95^{**}	1			
⑤k	0.42	−0.12	-0.84^{**}	-0.87^{**}	1		
⑥F	0.21	0.41	−0.14	−0.21	0.03	1	
⑦ℓ	−0.46	−0.33	0.34	0.39	−0.2	-0.69^{**}	1

($p<0.05,^{*}p<0.01,^{**}$)

We examined patterns of the acceleration and deceleration phases for sprinters of different record levels. Figure 4 shows relationships between the official record and ℓ. Three groups, except men world class, showed higher ℓ values with better records. We examined the correlation between A and k, as shown in Figure 5. The relationships between A and k tended to be negative in each group. All groups except men world class had a convex speed pattern, moderate acceleration and deceleration of the speed. The men world class had the best records with larger k and A, and smaller ℓ. As exception, their speed pattern showed rapid acceleration to higher speed and took more time to reach the maximum speed with larger deceleration but a shorter period. The equation (3) is a multiple regression equation to predict 100m sprint for the men world class.

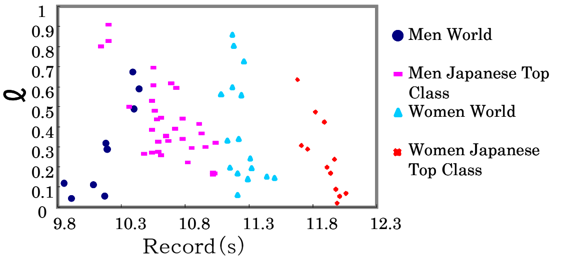

Figure 4 Relationship between record and ℓ

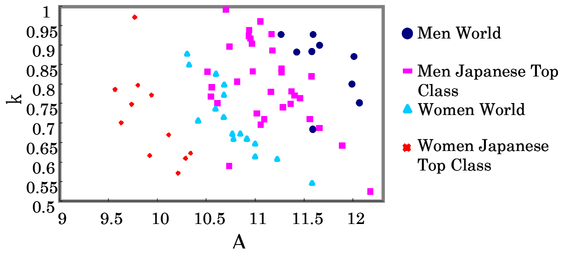

Figure 5 Relationship between A and k

$$\text{Record}=(-0.66\times A) + (-0.88\times k) + (-0.08\times F) + (-0.18\times \ell) + 18.6 \quad (3)$$

From equation (3), we can recommend increasing A and k for the improvement of the 100m sprint performance.

CONCLUSIONS:

1) The exponential equations proposed in this study well estimated the speed change pattern of the 100m running for the different record groups. The maximum speed was the most important factor for both men and women sprinters to achieve a best performance in the race. 3) The men's world class sprinters accelerated quickly (large k), but reached the maximum speed later than the other sprinters, which resulted in the shorter deceleration phase and smaller decrease in speed after reaching the maximal speed.

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