

Performance Analysis of Men's 110-m Hurdles using Rhythmic Units

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Objective: This study aimed to create a strategic training method to enhance optimal athletic ability using information from 1H to 10H rhythmic units.

Method: Top three world class athletes and three national winners of 110-m hurdle finals from the 2010 Daegu International Athletics Competition and 2017 National Athletics Championship, respectively, were selected. To analyze the kinematic variables, Dartfish 9.0 was used for two-dimensional analysis.

Results: Regarding the interval time from the start to the finish line, the national athletes took less time during the pure acceleration phase (start to 1H) than the foreign athletes. The horizontal velocity increase was slower after 1H; the national athletes showed a lack of ability to accelerate at the interval phases. Moreover, the hurdle clearance time between phases was longer in the national athletes than in the foreign athletes and lacked consistency.

Conclusion: The national athletes lacked the ability to accelerate at the transition, maximum rhythm, rhythm maintenance, and re-acceleration phases and showed a longer hurdle clearance time. If technical improvements and strategic training methods using rhythmic units are applied for hurdling motions, the national athlete's hurdling abilities, performance, and consistency could improve.

Keywords: Hurdle, Rhythmic units, Horizontal velocity, Clearance time, Strategic training method

INTRODUCTION

Hurdling is an event that requires sprinting and jumping abilities to clear hurdles, the obstacles that appear on the track. The athletic abilities that are important in hurdling events are acceleration from the start to the first hurdle and the series of connecting motions in the hurdling and interval phases with acceleration in between hurdles; maintaining consistent strides in the sprint phase after landing is also required (Mann & Herman, 1985; Stein, 2000). Hurdling skills involve the technical motion of clearing each hurdle as low and quickly as possible, and the flight phase where transition from sprinting before clearing a hurdle to running in between hurdles after landing occurs has the biggest impact on performance. Because of these reasons, previous studies in Korea and abroad have analyzed hurdling motions in specific phases and running motions in between hurdles to present quantitative data for improving performance.

With respect to 3H, 4H, 5H, and 6H, which are specific hurdle intervals in a 110-m hurdling event for Korean and international hurdlers, previous studies have divided them by hurdling motions and interval phases; the motions were divided to analyze the kinematic variables for optimal hurdling posture (Kang & Lim, 2002; Lee, 2004; Lim, Chung & Lee, 1994). Other studies have investigated kinematic variables for hurdling and running motions in hurdle phases where the maximum

velocity is reached (Coh, 2003; Park et al., 2011). In addition, kinematic analyses on hurdling and running motions have also been performed on the point where the maximum acceleration begins (Lee, 2009; Lee, Park, Ryu & Kim, 2008; Susanka, Miskos, Millerova, Dostal & Barac, 1988). Previous studies have attempted to help improve hurdling skills by analyzing hurdling motions in specific phases and points of maximum velocity and acceleration. While these studies have also attempted to present strategic methods for improving performance in all phases of hurdling events using kinematic data from hurdling motions and interval phases in between hurdles, they were unable to provide sufficient information or present strategic training methods.

A hurdling event requires athletic abilities, such as a high skill level to clear the hurdle while running, as well as quickness, speed, fitness, coordination, timing, and balance (Coh, 2003; Noh, 2014). In an actual competition, slight differences in these skills determine the order of finish. Each athlete has different athletic abilities; however, elite athletes would show very minimal differences among each other. Therefore, it is necessary for studies to divide the entire hurdling event into five phases (i.e., pure acceleration phase [PAP], transition phase [TP], maximum rhythm phase [MRP], rhythm maintenance phase [RMP], and re-acceleration phase [RAP]), as classified by Seagrave (1996), to present strategic training methods that can improve performance based on the most basic kinematic variables (time and velocity), while also predicting

S T A R T	PURE ACCELERATION PHASE		TRANSITION PHASE		MAXIMUM RHYTHM PHASE		RHYTHM MAINTENANCE PHASE		RE-ACCEL PHASE	F I N I S H
	IN	OUT 1stH	IN	OUT 4thH	IN	OUT 7thH	IN	OUT 10thH	IN	
	Start - 1st Hurdle		1st Hurdle - 4th Hurdle		4th Hurdle - 7th Hurdle		7th Hurdle - 10th Hurdle		10th Hurdle - Finish	

Figure 1. Phases of the 110-m hurdling event (Seagrave, 1996)

performance based on such variables.

Using rhythmic units (RUs) is a strategic method for improving the consistency of time and velocity required to clear all hurdles from start to finish by calculating the time required for each hurdling phase and average velocity based on the personal record of the athlete. In a sprint hurdling event, it is necessary to increase the stride length and frequency for maintaining velocity and efficient acceleration. Moreover, coaches in the field recognize that training is needed to overcome insufficient stride length in the distance between two hurdles. One of the training methods to overcome this is to run in between hurdles with a stride length with a lower percentage than the full sprint stride, and such a training can help maintain a high stride frequency and good rhythm (Coh & Dolence, 1996; Hucklekemkes, 1990; Muller & Hommel, 1997; Winckler, 1994).

The purpose of this study was to provide data with a high utilization value in the field by presenting methods that can predict personal records and a strategic training method for improving performance through calculation of quantitative simulation data on velocity and time using RUs for all hurdling phases.

METHODS

1. Participants

The study included three Korean athletes who were top finishers in the men's 110-m hurdle finals during the 2017 National Athletics Championship of Korea (average height: 1.86 ± 0.05 m, average weight: 78.67 ± 6.35 kg, and record: 13.92 ± 0.26 sec) and three foreign athletes who were top finishers in the men's 110-m hurdle finals during the 2010 Daegu International Athletics Competition (average height: 1.89 ± 0.04 m, average weight: 85.00 ± 7.00 kg, and event record: 13.26 ± 0.15 sec).

2. Measurements

To record the actual competition during the 2017 National Athletics Championship of Korea, a total of 10 Sony video cameras (FDR-AXP35; Sony, Japan) were set up along the track from the starting line and to the stands on the right side. A total of 24 range poles, 2 m in size, were set up at a right angle to the track from the starting line to the finish line and on the floor of the track. The range poles were set up with a distance of 13.72 m between the starting line and the first hurdle,

with 9.14 m in between two hurdles and 14.02 m between the last hurdle and the finish line. Dartfish 9.0 was used for two-dimensional calibration. The sampling rate was set at 60 fields/sec and the shutter speed at 1/500 sec. For the men's 100-m hurdling event of the 2010 Daegu International Athletics Competition, a total of seven JVC video cameras (GR-HD1KR; Japan Victor Company, Japan) were set up from the starting line to the finish line, with three cameras in the back and four cameras on the side. A total of 36 range poles, 2 m in size, were set up from the starting line to the finish line, along the inner lines of lanes 3, 4, and 5 and spaced apart to match the distance between the hurdles. The sampling rate was set at 60 fields/sec and the shutter speed at 1/500 sec.

3. Data processing

The study used the analyzer function in Dartfish 9.0 to calibrate the distance and calculated the time required and horizontal velocity for each phase. Here, the kinematic variables were analyzed by dividing them into five phases as shown in (Figure 1) (Seagrave, 1996). The five phases included the PAP - from the starting line to 1H; TP - from 1H to 4H; MRP - from 4H to 7H; RMP - from 7H to 10H; and RAP - from 10H to the finish line. The analysis phases by events comprised as follows: 1) from the moment the hand lifted off the starting line to landing after clearing 1H; 2) from landing in each hurdling phase to landing after clearing the last hurdle; and 3) from landing after clearing the last hurdle to the chest crossing the finish line.

Using the data obtained from the videotaping and analysis, RUs consisting of quantitative simulation data for the time required in each hurdling phase were calculated as shown in (Table 1) (Klestinski, 2014).

1) RU calculation method

The RUs were calculated using the personal event time, time required from the starting line to clearing the first hurdle, and time required from clearing the last hurdle to the finish line. Here, the time required to clear nine hurdle units (1H-2H, 2H-3H, [...] 9H-10H) did not include the time required in the starting and finishing phases, and the average RU for the hurdle units was calculated. Moreover, by dividing 82.26 m, the distance covering nine hurdle units, by the time required to clear nine hurdle units, the average velocity for the RU can be derived; this velocity value becomes the distance between hurdles in step 1. Next,

Table 1. Rhythmic unit (RU) calculation method

Hurdle personal best = sec	
Time to 1H = sec	9H * 9.14 m = 82.26 m
Run off to finish = sec	
Time from 1H to 10H = sec	9.14 m/average velocity for RUs
Average RU for nine hurdle units = sec	82.26 m/time from 1H to 10H
Average velocity for RU = m/sec	
Set drill with hurdle spacing at: m	
Increase distance each step by: 10 cm	
Goal is to run 1.00 sec for RU	

the distance of each step was increased by an increment of 10 cm to set up the steps in the five phases. Here, the goal of the RU for each step was 1 sec, while the hurdle height was 0.914~0.991 m. Moreover, once the goal for each step was achieved, the predicted personal record was calculated by multiplying nine to the RU in the step phase achieved in that athlete's actual RU (average RU for nine hurdle units), which yielded the predicted time required (sec) for nine hurdles. Moreover, by adding the actual time required in the starting and finishing intervals to the predicted time required to clear nine hurdles, the overall predicted personal record was derived.

RESULTS

The time for each phase from start to finish is shown in (Table 2). In the PAP (start to 1H), the Korean national athletes required a

Table 2. Interval time from the start to the finish line

(unit: sec)

Subjects	PAP	TP			MRP			RMP			RAP	
	Starting line to 1H	1H-2H	2H-3H	3H-4H	4H-5H	5H-6H	6H-7H	7H-8H	8H-9H	9H-10	10H to finish line	
National	A	2.634	1.133	1.067	1.067	1.000	1.133	1.033	1.067	1.067	1.067	1.433
	B	2.620	1.100	1.100	1.100	1.033	1.100	1.067	1.067	1.100	1.100	1.467
	C	2.650	1.133	1.100	1.133	1.133	1.067	1.100	1.100	1.133	1.133	1.500
M ± SD	2.635 ±0.02	1.122 ±0.02	1.089 ±0.02	1.100 ±0.03	1.055 ±0.07	1.100 ±0.03	1.067 ±0.03	1.078 ±0.02	1.100 ±0.03	1.100 ±0.03	1.467 ±0.03	
Foreign	D	2.605	1.051	1.017	0.984	1.000	0.984	1.000	1.017	1.017	1.067	1.368
	E	2.688	1.067	1.000	0.984	1.017	1.000	1.000	1.017	1.051	1.051	1.401
	F	2.633	1.084	1.000	1.000	1.017	1.034	1.051	1.034	1.067	1.067	1.368
M ± SD	2.645 ±0.04	1.067 ±0.02	1.006 ±0.01	0.989 ±0.01	1.011 ±0.01	1.006 ±0.03	1.017 ±0.03	1.023 ±0.01	1.045 ±0.03	1.062 ±0.01	1.379 ±0.02	

PAP: Pure acceleration phase, TP: Transition phase, MRP: Maximum rhythm phase, RMP: Rhythm maintenance phase, RAP: Re-acceleration phase, M ± SD: Mean ± Standard Deviation

Table 3. Interval velocity from the start to the finish line

(unit: m/sec)

Subjects	PAP	TP			MRP			RMP			RAP	M ± SD	
	Starting line to 1H	1H-2H	2H-3H	3H-4H	4H-5H	5H-6H	6H-7H	7H-8H	8H-9H	9H-10H	10H to finish line		
National	A	5.21	8.06	8.57	8.57	9.14	8.06	8.85	8.57	8.57	8.57	9.78	8.55±0.34
	B	5.24	8.31	8.31	8.31	8.85	8.31	8.57	8.57	8.31	8.31	9.56	8.43±0.19
	C	5.18	8.06	8.31	8.06	8.06	8.57	8.31	8.31	8.06	8.06	9.35	8.20±0.18
Foreign	D	5.27	8.70	8.99	9.29	9.14	9.29	9.14	8.99	8.99	8.57	10.25	9.01±0.25
	E	5.14	8.57	9.14	9.29	8.99	9.14	9.14	8.99	8.70	8.70	10.01	8.96±0.25
	F	5.15	8.43	9.14	9.14	8.99	8.84	8.70	8.84	8.57	8.57	10.25	8.80±0.26

PAP: Pure acceleration phase, TP: Transition phase, MRP: Maximum rhythm phase, RMP: Rhythm maintenance phase, RAP: Re-acceleration phase, M ± SD: Mean ± Standard Deviation

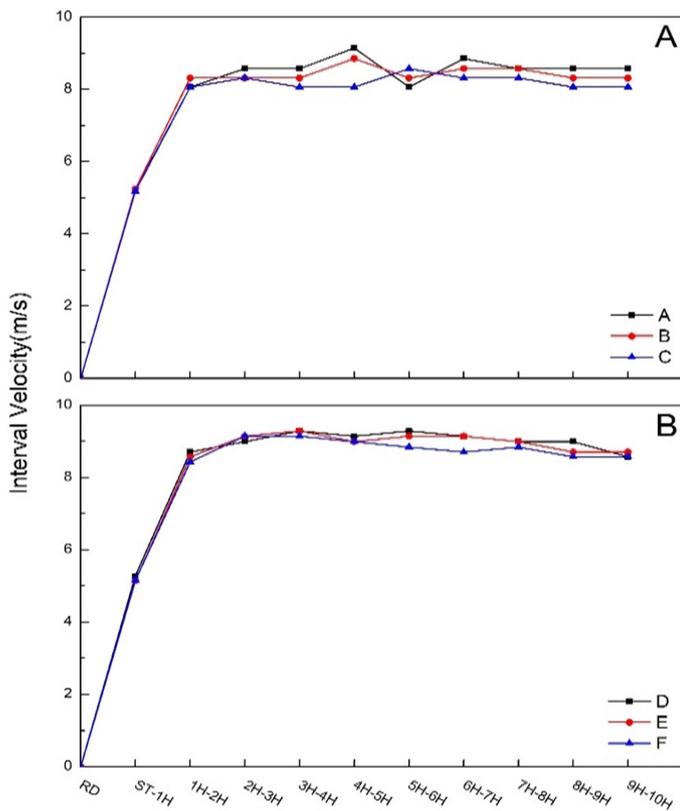


Figure 2. Interval velocity from the start to the finish line (A: national athletes; B: foreign athletes)

shorter time on an average of 0.010 sec than the foreign athletes. In the TP (1H-4H), the national athletes required a longer time on an average of 0.200 sec than the foreign athletes. In the MRP (4H-7H), the national athletes required a longer time on an average of 0.300 sec than the foreign athletes. In the RMP (7H-10H), the national athletes also required a longer time on an average of 0.100 sec than the foreign athletes. In the RAP (10H to finish), the national athletes again required a longer time on an average of 0.088 sec than the foreign athletes.

The horizontal velocity in each phase from start to finish is shown in (Table 3) and (Figure 2).

While the foreign athletes showed an average horizontal velocity of over 8.80 m/sec between 1H and 10H, the national athletes showed an average horizontal velocity of below 8.55 m/sec. National athlete "A" showed a horizontal velocity of 9.14 m/sec in 5H of the MRP (4H-7H), which was comparable to that of the foreign athletes; however, the velocity decreased thereafter. However, all national athletes showed a slower horizontal velocity than the foreign athletes in all phases, except for the PAP; the MRP showed the largest margin of change in the horizontal velocity.

The hurdle clearance time for each phase from start to finish is shown in (Table 4).

With respect to the hurdle clearance time, the foreign athletes showed a mean time of below 0.336 sec, whereas the national athletes showed a mean time of over 0.390 sec. For the hurdle clearance time between 1H and 10H, the national athletes required an average of 0.078 sec longer to clear the hurdles than the foreign athletes.

The RUs calculated from the analyzed kinematic variables and personal record of each athlete are shown in (Table 5). The average RU of athlete "A" for nine hurdles was 1.07 sec, and the record of 13.70 sec from the actual event was similar to the predicted record of 13.69 sec. The average RU of athlete "B" for nine hurdles was 1.09 sec, and the record of 13.86 sec from the actual event was similar to the predicted record of 13.90 sec. The reason why the difference between the actual and predicted records was 0.04 sec was because the average RU for nine hurdles was actually 1.086 sec. The average RU of athlete "C" for nine hurdles was 1.11 sec, and the record of 14.20 sec from the actual event was similar to the predicted record of 14.15 sec. The reason why the difference between the actual and predicted records was 0.05 sec was because the average RU for nine hurdles was actually 1.117 sec.

DISCUSSION

A 110-m hurdling event is a short-distance track event in which the athletes attempt to cross the finish line in the shortest time possible after clearing 10 evenly spaced hurdles. The factors affecting the overall performance are hurdle clearance time consistency in each phase and horizontal velocity increase and maintenance.

In this study, the course from start to finish was divided into five

Table 4. Hurdle clearance time

(unit: sec)

Subjects	TP			MRP			RMP				M ± SD	
	1H	2H	3H	4H	5H	6H	7H	8H	9H	10H		
National	A	0.367	0.367	0.400	0.400	0.367	0.367	0.400	0.367	0.433	0.433	0.390±0.03
	B	0.400	0.400	0.367	0.400	0.400	0.400	0.400	0.400	0.367	0.367	0.390±0.02
	C	0.433	0.433	0.433	0.433	0.433	0.467	0.400	0.433	0.433	0.433	0.433±0.02
Foreign	D	0.333	0.316	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.316	0.307±0.01
	E	0.333	0.350	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.350	0.336±0.01
	F	0.333	0.350	0.316	0.333	0.333	0.333	0.333	0.350	0.333	0.333	0.335±0.01

TP: Transition phase, MRP: Maximum rhythm phase, RMP: Rhythm maintenance phase, M ± SD: Mean ± Standard Deviation

Table 5. Players A, B, and C's rhythmic units (RUs)

(unit: sec)

Player A							Player B							Player C						
Hurdle personal best = 13.70 sec							Hurdle personal best = 13.86 sec							Hurdle personal best = 14.20 sec						
Time to 1H = 2.63 sec							Time to 1H = 2.62 sec							Time to 1H = 2.65 sec						
Run off to finish = 1.43 sec							Run off to finish = 1.47 sec							Run off to finish = 1.50 sec						
RU	Step 1	Step 2	Step 3	Step 4	Step 5	Predicted record	RU	Step 1	Step 2	Step 3	Step 4	Step 5	Predicted record	RU	Step 1	Step 2	Step 3	Step 4	Step 5	Predicted record
	8.53 m	8.63 m	8.73 m	8.83 m	8.93 m	9.14 m 110H		8.42 m	8.52 m	8.62 m	8.72 m	8.82 m	9.14 m 110H		8.19 m	8.29 m	8.39 m	8.49 m	8.59 m	9.14 m 110H
RU	110H	110H	110H	110H	110H	110H	RU	110H	110H	110H	110H	110H	110H	RU	110H	110H	110H	110H	110H	110H
1.11	14.76	14.64	14.52	14.40	14.28	14.05	1.11	14.94	14.81	14.68	14.56	14.44	14.08	1.11	15.31	15.17	15.04	14.91	14.79	14.15
1.10	14.66	14.54	14.42	14.30	14.19	13.96	1.10	14.84	14.71	14.59	14.47	14.35	13.99	1.10	15.21	15.07	14.94	14.81	14.69	14.06
1.09	14.57	14.45	14.33	14.21	14.10	13.87	1.09	14.74	14.61	14.49	14.37	14.26	13.90	1.09	15.10	14.97	14.84	14.72	14.59	13.97
1.08	14.47	14.35	14.23	14.12	14.01	13.78	1.08	14.64	14.52	14.40	14.28	14.16	13.81	1.08	15.00	14.87	14.75	14.62	14.50	13.88
1.07	14.37	14.26	14.14	14.02	13.91	13.69	1.07	14.54	14.42	14.30	14.18	14.07	13.72	1.07	14.90	14.77	14.65	14.52	14.40	13.79
1.06	14.28	14.16	14.04	13.93	13.82	13.60	1.06	14.45	14.32	14.21	14.09	13.98	13.63	1.06	14.80	14.67	14.55	14.43	14.31	13.70
1.05	14.18	14.06	13.95	13.84	13.73	13.51	1.05	14.35	14.23	14.11	14.00	13.88	13.54	1.05	14.70	14.58	14.45	14.33	14.21	13.61
1.04	14.09	13.97	13.86	13.75	13.64	13.42	1.04	14.25	14.13	14.02	13.90	13.79	13.45	1.04	14.60	14.48	14.35	14.23	14.12	13.52
1.03	13.99	13.87	13.76	13.65	13.54	13.33	1.03	14.15	14.04	13.92	13.81	13.70	13.36	1.03	14.50	14.38	14.25	14.14	14.02	13.42
1.02	13.89	13.78	13.67	13.56	13.45	13.24	1.02	14.06	13.94	13.82	13.71	13.60	13.27	1.02	14.40	14.28	14.16	14.04	13.92	13.33
1.01	13.80	13.68	13.57	13.47	13.36	13.15	1.01	13.96	13.84	13.73	13.62	13.51	13.18	1.01	14.30	14.18	14.06	13.94	13.83	13.24
1.00	13.70	13.59	13.48	13.37	13.27	13.06	1.00	13.86	13.75	13.63	13.52	13.42	13.09	1.00	14.20	14.08	13.96	13.84	13.73	13.15
0.99	13.60	13.49	13.39	13.28	13.18	12.97	0.99	13.76	13.65	13.54	13.43	13.32	13.00	0.99	14.10	13.98	13.86	13.75	13.64	13.06

phases. In the PAP, the national athletes required a shorter time on an average of 0.010 sec and showed a faster velocity by 0.02 m/sec than the foreign athletes, which indicated that the national athletes had superior quickness out of the starting block and acceleration ability. However, in the study by Graubner and Nixdorf (2011) on top finishers in the 2009 World Championships in Athletics, the average time required in the PAP was 2.547 sec, which was faster by 0.088 sec than that shown by the national athletes in the present study. Such a difference may be because of the differences in the reaction speed of athletes in getting out of the starting block, stride number in the first hurdle, and acceleration ability.

In the TP, the national athletes required a longer time on an average of 0.249 sec; their horizontal velocity was on an average of 0.69 m/sec. Particularly in the MRP, the time required was longer by an average of >0.300 sec, while the horizontal velocity was lower by an average of 0.52 m/sec. In the RMP, the time required was longer by an average of 0.100 sec, while the horizontal velocity was lower by an average of 0.40 m/sec. Lastly, in the RAP, the time required was 0.088 sec on average, despite the fact that the personal record could be improved by running without clearing any hurdles in this phase. Although the difference was smaller than that in the other three phases, this phase was longer, while the average difference in the horizontal velocity was 0.61 m/sec, which presented the second largest difference.

The reason why the national athletes required a longer time in the

three phases that required hurdle clearance was because the average time for the national athletes to clear the hurdles from 1H to 10H was 1.090 sec, which was 0.066 sec longer than that of the foreign athletes. This is because the national athletes were taller and showed a longer time during the flight phase than the foreign athletes, and because their subsequent transition to running motions in the interval phase was not smooth, their horizontal velocity was lower than that of the foreign athletes.

Ryu and Chang (2011) reported that performance can be improved by minimizing deceleration after hurdle clearance by a shorter flight time. Moreover, Coh and Dolence (1996) reported that since flight time is affected by various kinematic variables, it affects the athlete's performance, and it is important to maintain a consistent flight time when clearing each hurdle. Just as previous researchers have viewed flight time as an important factor, the national athletes showed a too long and inconsistent flight time during hurdle clearance. Therefore, improvement is needed to develop skills that can reduce their flight time during hurdle clearance. Accordingly, the factors important for reducing the time required in motions to clear hurdles are consistent distance between the hurdle and lift-off foot, as well as technique, coordination, timing, and balance of the arms and legs during hurdling motions. Moreover, the factors important for increasing the horizontal velocity with the distance of 9.14 m between two hurdles are consistency in stride length, improved techniques to increase the frequency or pitch

rate, and strategic training. Combining these factors can help reduce the flight time during hurdle clearance and increase the horizontal velocity in interval phases.

The national athletes (average, 1.090 sec) required a longer time to clear the hurdles from 1H to 10H than the foreign athletes (average, 1.024 sec), where 1H to 10H represented the TP, MRP, and RMP of the five phases presented by Seagrave (1996). Therefore, it is necessary to explore strategic training methods that can help overcome this difference of 0.066 sec in the average time. To resolve this, simulation using RUs designed by Klestinski (2014) was used to calculate the time required in the five phases; as a result, the personal records of the national athletes from the actual events and predicted values calculated by the RUs were similar. Thus, a training method based on RUs may be considered to have a utilization value in the field.

For improving the performance of Korean national athletes, this study calculated the RUs from step 1 to step 5 based on the personal records of three national athletes (time from the starting line to clearing the first hurdle and time from clearing the last hurdle to crossing the finish line). A strategic training program based on RUs must achieve the target value for each step in a step-wise manner. With the target RU for each step set at 1.00 sec, athlete "A" was required to finish step 1 with hurdles set up 8.53 m apart in 13.70 sec. Moreover, if the target time for step 1 is achieved, a personal record of 13.60 sec could be predicted when running between hurdle distances of 8.93 m in an official 110-m hurdling event. After achieving the target value for each step, if athlete "A" completed the 110-m hurdling event at 13.27 sec by maintaining the target RU of 1.00 sec for the distance of 8.93 m in between hurdles up to phase 5, then based on the base RU of 1.07 sec, it would correspond to 1.02 sec below step 5; here, the predicted personal record would be 13.24 sec. Further, an error of 1 cm in the distance of step 2 shown in (Table 5) occurred because the distance in the four remaining steps was uniformly increased by 10 cm based on the distance between hurdles calculated in step 1. When the RUs of athletes "B" and "C" were calculated using the same calculation used on athlete "A", the following results were derived. Athlete "B" would clear the remaining nine hurdles at 1.08 sec if the target RU of 1.00 sec is achieved in step 1, and the total time required would be 13.81 sec: 9.72 sec required to clear the hurdles, 2.63 sec in the starting phase, and 1.47 sec in the finishing phase. Athlete "C" would clear the remaining nine hurdles at 1.11 sec if the target RU is achieved in step 1, and the total time required would be 14.15 sec: 9.99 sec required to clear the hurdles, 2.65 sec in the starting phase, and 1.50 sec in the finishing phase.

The points to consider when starting such a strategic training program include adjusting the stride length within the distance in between hurdles and adjusting the stride number to the desired frequency, while maintaining a consistency point of take-off when approaching a hurdle. Additionally, effort must be taken to adapt to the rhythm of the stride length adjusted in between hurdles and new increased stride frequency. Here, the athlete must be able to run with gradually longer strides, while maintaining the adjusted stride frequency. The problems that may arise while adjusting the stride frequency include as follows: 1) difficulty with efficient take-off, since the hurdle is being cleared at a faster speed; 2) timing involved in the transition from hurdle clearance

to running; 3) difficulty with increasing velocity of the running motion (three steps) in between hurdles; and 4) the take-off point for the next hurdle becomes closer. Therefore, to apply the training method using RUs, consistency of motions when clearing hurdles must be achieved first.

CONCLUSION

This study used the personal records of athletes and required time in the five phases (i.e., PAP, TP, MRP, RMP, and RAP) presented by Seagrave (1996) to develop a strategic training method comprising a step-wise application of RUs between 1H and 10H in men's 110-m hurdling events. Based on the analysis results of the required time by each phase, horizontal velocity, and RUs for all phases of a 110-m hurdling event, the following conclusions were derived:

1. In the PAP (start to 1H), the national athletes required a shorter time than the foreign athletes, whereas in the TP (1H-4H), MRP (4H-7H), RMP (7H-10H), and RAP (10H to finish), the required time was longer. In other words, the national athletes lacked the acceleration ability in the interval phases, and their hurdling time was longer.

2. The strategic training program using RUs showed that the personal records measured from an actual event were similar to the predicted records calculated by the RUs. Therefore, such a method can be viewed as a strategic training method for improving and predicting future performance.

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