APPLICATION OF FILMING AND MOTION ANALYSIS IN MOVEMENT STUDIES

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The sports biomechanics branch of Singapore Sports Council (SSC) was established in 1995. Since its inception, video analyses have been conducted in studies of sporting activities such as high jump, badminton, discus, hammer, javelin throw etc. Video recordings of the sporting activities are recorded in training sessions as well as during competitions (e.g. South East Asian Games, Singapore Open Track & Field Championship, Konica Cup). In 1998, a new biomechanics laboratory was developed to improve the facilitation of biomechanical studies. In this paper, three applications of video analysis are presented in the aspect of technique analysis, monitoring and improvement.

KEY WORDS: video filming, motion analysis, discus, hammer, high jump

INTRODUCTION: The objective of the formation of the biomechanics branch in sports science department of Singapore Sports Council is to assist coaches to enable their athletes, to improve their techniques or performances. The services provided by the biomechanics laboratory can be divided into the following:

(1) Recording of video images for qualitative analysis - The staff of the biomechanics branch would not only assist in the video recording but also provide video cameras (50 and 200 fields/sec) and other equipment so that the performance of the athletes in training sessions and competitions can be effectively recorded. These recordings are used directly by the coaches to analyze athletes' performance. Examples of such work are: underwater video for swimming, pistol and rifle shooting, video recording of Chinese Wushu, bowling, and fencing using high speed video camera.

(2) Analysis of quantitative data - The biomechanics laboratory also provides two-dimensional or three-dimensional motion analysis for selected sports. Basically the staff would record, digitize and analyze sports performance in the laboratory, training sessions as well as in competitions. The results obtained from such analyses were then made available to coaches and occasionally recommendations based on these analyses are also provided to assist the athletes in improving their performances.

(3) Research and development projects - The biomechanics branch has also the responsibility of developing equipment for research and performance assessment. The laboratory has developed equipment for technique analysis, tactical (notational) analysis and risk analysis of injury.

With the construction of the new sports biomechanics laboratory completed, certain sporting activities (e.g. high jump, discus) could be performed in the laboratory. As such the video recording and motion analysis can be engaged in the laboratory. Monitoring athletes' techniques can be conducted more effectively mainly because the process could be carried out without the interference due to inclement of weather.

This paper outlines three projects that were carried out in the last three years. The projects are (1) discus throw – improvement of the technique, (2) hammer throw – failure analysis, and (3) high jump – technical monitoring in indoor training.

A Singapore national discus and hammer thrower (named ADH in this paper) was the gold medalist in both the men's discus and hammer throw at the 19th South East Asian (SEA) Games in 1997. To improve his performance, a biomechanical project was conceived and implemented. In order to gain an insight to his discus and hammer throwing technique, motion analysis of his techniques were conducted. The results of the study with suggestions of how he could improve his performance were presented to the athlete and his coach. Two years later, his discus performance was noted to have improved. His personal best for discus throw increased by 5.85 m (from 54.02m to 59.87m). However, his performance in the hammer event did not improve. The change in technique and the factors that influenced his performance will be discussed in this paper.

In 1999 before the 20th SEA Games, a indoor training and technique monitoring project was implemented to assist a Singapore national jumper in his performance (he is named as AHJ in this paper). Both kinematic and kinetic equipment were used to monitor his performance.

METHOD: Data collection and reduction. Video cameras with genlock function and zoom lenses were used in video recording and the image recordings were then digitized and analyzed. Some of the video images were recorded in color and at normal speed (50 fields/sec) by Panasonic WV-CP450 video cameras, others were recorded in black/white and at high speed (200 fields/sec) by PEAK HSC-200 high-speed video cameras. The two types of recordings were then digitized and the performance variable were processed with the Peak motion analysis (version 3.0 and 4.3) system.

1. Discus and hammer. For discus and hammer throws, video for three-dimensional motion analysis was recorded by using three video cameras at 50 fields/sec (for hammer) and 200 fields/sec (for discus) during 1997 Nike 59th Singapore Open and the 19th South East Asian Games. Figure 1a shows the locations of cameras used for these studies. Each camera was about seven meters away from the center of throwing circle.

The following performance variables of discus were obtained from data analysis:

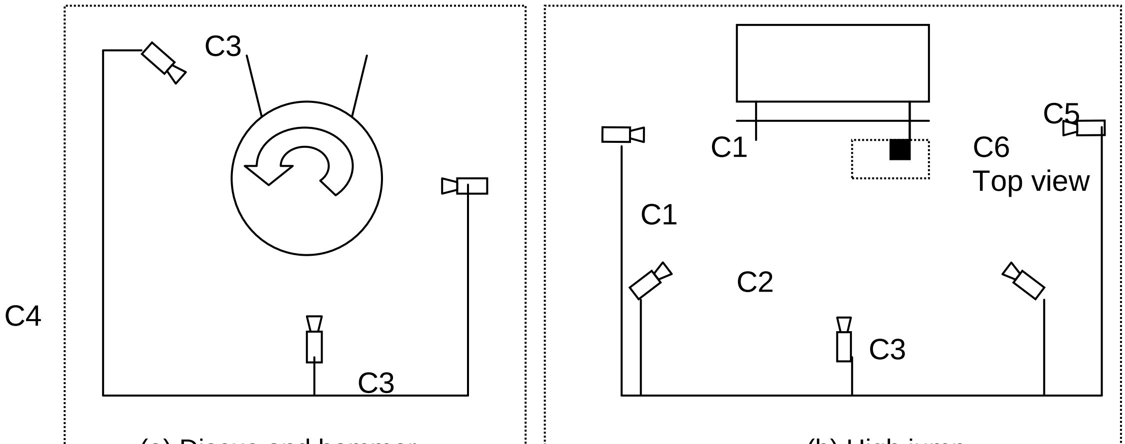
(1) Release parameters of the discus. (2) 'Lost distance' at release. (3) Left foot position in the double-support duration of the delivery phase. (4) Speed lost during the second single support phase. (5) Time history of foot contact during the delivery. The performance variables were processed according to the method presented by Hay and Yu (1995).

The following performance variables of hammer were obtained from data analysis:

(1) Release parameters of the hammer. (2) Duration of double support phase. (3) The hammer position at the beginning and end of double-support phase. (4) Body position at the moment of planting the right foot. The performance variables were processed according to the method presented by Bartonietz and Borgström (1995).

The performance variables of the throws from these studies were then compared with those obtained from other studies (e.g. Hay & Yu, 1995 and Bartonietz & Borgström, 1995) that used subjects who are world class athlete. The results of the video analyses and the comparison with the other elite athletes were presented to the athlete and his coach. Recommendations of changes in throwing technique were also presented to the thrower and his coach. In 1999, two years after the initial video analysis, another video analysis was performed on ADH's discus and hammer throwing techniques during practice. The performance variables were processed and then compared with that of his previous effort and with that of the other throwers (reported by Hay & Yu, 1995 and Bartonietz & Borgström, 1995).

2. High jump. The indoor technique monitoring project was implemented for Singapore high jumpers in 1999 at the SSC biomechanics laboratory. Four Panasonic color video cameras (50 fields/sec) were used to capture video, and two AMTI OR6-6-2000 force platforms with 2 AMTI SGR6-4 amplifiers were used to collect data of three dimensional contact force at 1000Hz sampling rate for this analysis. The software BioDaq version 1.0 and BioSoft version 1.01 were used to acquire and process the data from force plates. The cameras and the force plates were synchronized. The location of cameras C2, C4, C5, C6 and the force platforms is shown in figure 1b, and the force platforms were installed at the take-off point. The jumper came to laboratory twice a week for training. During training, coach and jumper were able to view the performance from different views with the assistance of the video recordings. The data from the force plates were also presented to the athlete and the coach. Once the training session ended, the recorded video images were presented to the coach and jumper in a quad compressor ‘four in one’ screen to help them to review the jumps. Then the three-dimensional motion analysis would proceed for some selected trials. With these analyses performance variables such as duration of take-off and vertical velocity at take-off can be deduced. These performance variables of the jumps are compared with that the other elite jumpers of the region collected at competition. The cameras C1, C3 and C4 in figure 1b were used to capture video at competition.



(a) Discus and hammer (b) High jump

Figure 1 - Position of cameras and force platforms.

RESULT AND DISCUSSION: 1. Discus throw. The speed of release of the discus is the most important factor that contributes to the throwing distance. Table 1 shows the release parameters of ADH 's discus throw. From 1997 to 1999, his release speed of discus was increased by an average of 0.9 m/s (max, 1.3 m/s). But on the average, it was still 2.8 m/s less than that of world class throwers (as reported by Knicker, 1994).

Aerodynamic distance is the distance gained due to aerodynamic forces exerted on the discus during its flight. (Hay and Yu, 1995). The angle of release of the discus is the important factor in increasing the aerodynamic distance. ADH's average angle of release of the discus was 42.2 degrees in 1997 and 34.4 degrees in 1999. His average angle of release of the discus in 1999 were closer in values to that reported by Hay and Yu (1995) on their world class athletes**.** In fact, he gained more aerodynamic distance in 1999.

Table 1 Speed, Angle and Height of Release of the Discus and Aerodynamic Distance

	speed of release (m/s)			angle of release (°)			height of release (m)			aerodynamic distance (m)		
	Ave.	Max.	Min.	Ave	Max.	Min	Ave.	Max.	Min.	Ave.	Max.	Min.
ADH in 1997	21.9	22.0	21.8	42.2	43.2	41.4	1.68	1.71	1.60	1.18	2.32	0.10
ADH in 1999	22.8	23.3	22.5	34.4	36.0	32.6	1.79	1.85	1.68	5.03	6.52	3.16

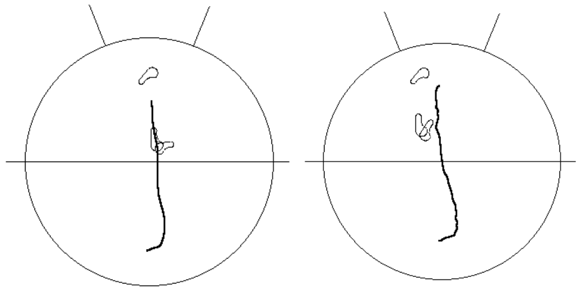
Distance lost at release is the horizontal distance that a discus travels in flight for which the athlete does not receive credit in the measurement of the official distance (Hay and Yu, 1995). ADH's average distance lost at release was 0.3 m in 1997 and 0.1 m in 1999.

For a right-handed thrower, the second single support phase is the duration from the right foot touchdown to the left foot touchdown (Hay and Yu, 1995). For ADH, the reduced second single support phase would reduce the discus speed loss in this phase, and therefore contributes to obtain the faster release speed that in turn will enable him to throw further. The average speed loss of the discus during second single support phase of the delivery was reduced from 1.81m/s in 1997 to 0.89m/s in 1999.

The double support phase in delivery is the duration when two feet of the athlete are on the ground. To a certain extent, the higher ratio of the double support phase to the total duration of the delivery would increase the time of accelerating discus and therefore be beneficial to achieve higher release speed. The ratio of the double support time to the total duration of delivery phase for ADH was 65.0% (average) for throws analyzed in 1999 and 63.0% for throw analyzed in 1997. There is little change in this aspect.

At the beginning of delivery phase, ADH planted his left foot in front of the right foot in 1997 (figure 2a). That would hinder his hip movement and accelerating discus. From data analysis in 1999, there is little change in the position of his left foot relative to the right foot (figure 2b).

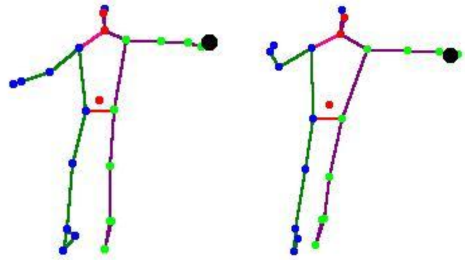
From the analysis of discus throws performed at the 19th SEA Game in 1997, the following recommendations were made to the thrower and his coach: (1) Reduce the release angle of discus (from 41~43 degrees to 35~39 degrees) to achieve a longer aerodynamic distance. (2) Keep the distance lost at release to a minimal. (3**)** Reduce the speed loss of discus during second single support phase by decreasing the duration of the phase. (4) Alter the landing position of the left foot to left side (in the face of throw direction) at the beginning of the delivery phase, to avoid hindering the hip rotation**.** (5) Extend the ratio of double support time in delivery phase to have longer time to accelerate discus.



(a) 54.08 m, 1997 (b) 58.66 m, 1999

Figure 2 - Foot position at planting left Foot (at beginning of

According to the data collected in 1999, the discus thrower was noted to have modified his technique of throwing as recommended. The significant changes are the decreasing of angles of release, shorter second single support phase, and reduced speed loss in second single support phase. Besides these changes, the thrower was noted to have inclined towards his right side in the delivery phase of the throw as compared to the body position at release adopted in 1997 (as illustrated in figure 3a and 3b). In this way, he was able to obtain a wider range of movement of right arm so as to increase the effective radius and the path of acceleration of the discus in the delivery phase.



(a) 54.08m, 1997 (b) 58.66m, 1999

Figure 3 - Body position at release of discus.

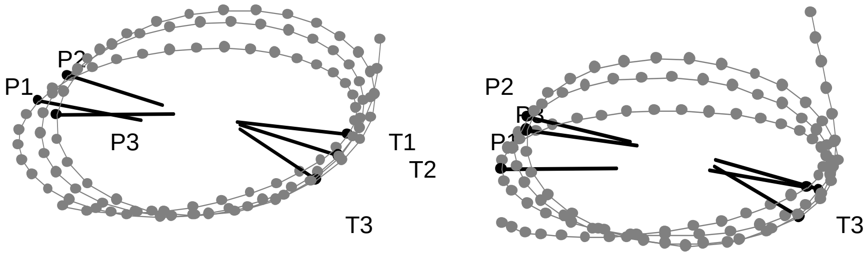
2. Hammer throw. Hammer throw is the other competitive event that ADH is engaged in. He uses the 'three-turn' technique. Table 2 shows speed, angle and height of release of the hammer and table 3 provides the duration of single and double foot support in each turn. The positions of hammer at planting and take-off of right foot in each turn are presented in Figure 4.

Table 2 Speed, Angle and Height of Release of the Hammer

	Speed (m/s)				Angle (degree)				Height(m)			
	Ave.	S.D.	Max.	Min.	Ave	S.D.	Max.	Min	Ave.	S.D.	Max.	Min.
ADH in 1997	23.8	0.42	24.3	21.8	42.5	1.15	44.2	41.0	1.73	0.12	1.82	1.62
ADH in 1999	23.3	0.44	24.1	22.8	40.0	0.94	41.8	38.8	1.68	0.06	1.78	1.62
Sedykh*	29.1				38.9				1.72			

P1 -- planting at 1st turn
P2 - planting at 2nd turn
P3 - planting at 3rd turn

T1 – taking-off at 1st turn
T2 – taking-off at 2nd turn
T1,T2
T3 – taking-off at 3rd turn



(a) 58.00 m, 1997 (b) 56.76 m, 1999

Figure 4 - Hammer Position at planting and take-off of right foot (back view).

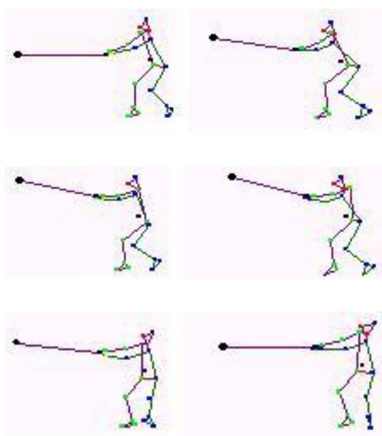
Table 3 Duration of Single and Double Support Phase

Duration (sec)		James 1997(n=5) Ave.	SD	%	James 1999(n=7) Ave.	SD	%	elite thrower*(n=5) Ave.	SD	%
1st turn	single	0.36	0.01	52.9	0.41	0.03	58.6	0.30	0.03	45.5
	double	0.32	0.01	47.1	0.29	0.02	41.4	0.36	0.03	54.5
	total	0.68	0.02		0.70	0.03		0.66	0.05	
2nd turn	single	0.34	0.02	55.7	0.35	0.02	59.3	0.26	0.02	51.0
	double	0.27	0.04	44.3	0.24	0.03	40.7	0.25	0.02	49.0
	total	0.61	0.04		0.59	0.02		0.51	0.02	
3rd turn	single	0.34	0.02	54.8	0.33	0.01	55.0	0.22	0.03	48.9
	double	0.27	0.03	45.2	0.27	0.03	45.0	0.23	0.03	51.1
	total	0.62	0.02		0.60	0.03		0.45	0.02	
4th turn	single							0.24	0.04	51.1
	double							0.23	0.03	48.9
	total							0.47	0.02	

* Based on data published by Bartonietz and Borgström (1995)

Since hammer throw is not the main competitive event for ADH, he did not allocate as much training time to this event as compared to the discus event. Although his performance in hammer throwing is relatively low compared to the world-class hammer throwers, he won the gold medal at 19th SEA Games in 1997. After analyzing his throws in 1997 several recommendations were made, such as: (1) to maintain the angle of release of hammer about 43 degrees, (2) to use longer double support phase, (3) to lower body position at the beginning of double support.

In 1999, ADH's hammer throws were analyzed and the results shown that both the release speed and angle of hammer were lower than that of his performance in 1997 (see table 2). This may be the main reason for the decline of his throwing distance. The ratio of double support duration in a turn to its total time taken for the whole turn was smaller than that of the world class athletes (reported by Bartonietz & Borgström, 1995). It was also smaller than his 1997 performance (see table 2). This reduction in ratio would influence the acceleration of the discus



(a) in first turn
(b) in second turn
(c) in last turn
in 1999 in 1997

Figure 5 - Body position at the planting of right foot.

and the release speed of discus. Figure 4 shows the hammer position at movement ADH planted and lifted-off his right foot in a throw. Assuming that the 'center line' of the throwing circle in the direction of throw is taken to be '12 o'clock' position, he planted his right foot at the beginning of double support phase around '9 o'clock' position and lifted his right foot around the '4 o'clock' position (as shown in figure 4). Comparing with the data of 1997, there is also no change of the body positions at the beginning of double support phase in 1999 (as shown in figure 5).

3. High jump. After each jump, the coach and jumper viewed the jumps through the compressed ‘four in one’ synchronized multiple-view video (see figure 6). The athlete and coach also noted the curves of the three-dimensional contact force. These provided qualitative and quantitative information for each individual jump. Table 4 presents the duration of take-off phase (contact time) and vertical velocity of AHJ and his competitors in Asia. The contact time of take-off phase of elite jumpers as reported by Tidow (1993), ranges from 0.12 to 0.17 seconds. The other Asian competitors participating in the 61th Singapore Open have contact times at take-off between 0.14 to 0.16 seconds. The average take-off time for AHJ is 0.18 seconds. This implies that AHJ's take-off time may be a little too long. The vertical velocity of his mass center at take-off was also smaller than that of a Malaysian competitor (referred in Table 4 as LKZ) competing in that meet. That implies his take-off phase was not as effective hence it was recommended that his technique at take-off should be re-examined.

Table 4 Duration of Take Off and Vertical Velocity

	Duration(sec)	vertical velocity (m/s)
AHJ (indoor, 2.00m)	0.19	4.0
AHJ (2.05m)*	0.18	3.8
LKZ (MAS, 2.19m)*	0.16	4.6
Other (Asian >2.1m)	0.14 ~ 0.16	

* Data collected from 61th Singapore Open (1999)

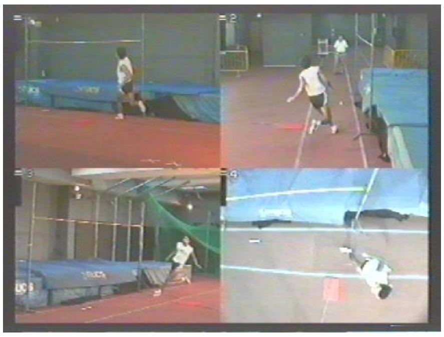


Figure 6 - Multiple-view video.

CONCLUSION: The application of video filming and motion analysis may help athletes and their coaches to examine the techniques used and to explore ways to improve their performance. With the assistance of technique analysis, ADH improved his performance in his discus throw by modifying his technique namely by increasing the release speed of discus and optimizing the release angle. From the 1999 analysis in the hammer throw, we were able to account for the decline in performance with the reduction of release speed and release angle of the hammer.

Technique monitoring is a helpful process in identifying the factors that influence the outcome of the performance. The noted longer contact time at the take-off phase with the corresponding lower vertical velocity of center of mass indicate that the jumper's take-off was not as efficient as the other elite jumpers.

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