COMPARATIVE ANALYSIS OF YANG HAK-SEON VAULT AND TSUKAHARA 1260° VAULT IN GYMNASTICS

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The study was a single-subject study on the top-elite vaulter in the world. This study was purposed to compare kinematic differences between Yang Hak-Seon vault (Yang-1) and Tsukahara 1260° vault (Yang-2) performed by Yang Hak-Seon. Fourteen high-speed cameras were used to capture a whole body segment motion of Yang-2 vault during the practice session. Yang-1 vault showed faster CM vertical velocity until the vault table takeoff and faster CM horizontal velocity prior to the vault table touchdown. However, the trunk rotation angle and its angular velocity of Yang-2 vault exceeded Yang-1 vault significantly. This might be due to a half turn off the springboard onto the vault table of Yang-2 vault, which resulted in larger initial angular momentum at the vault table touchdown and further increase in angular velocity during the vault table contact.

KEY WORDS: Yang-1, Yang-2, vault, gymnastics, kinematics.

INTRODUCTION: Yang Hak-Seon (YHS) won a gold medal in vault of gymnastics in 2012 London Olympic Games by the help of his signature technique, Yang Hak-Seon vault (Yang-1 vault). This technique was registered in International Gymnastics Federation (FIG) as the highest D-score of 7.4 at that time. The D-score of Yang-1 vault, however, was recently dropped one point under a new scoring system by FIG so that Yang has tried to develop another enhanced technique for defending his gold in the next Olympic Games.

Recently YHS has practiced a new technique, Tsukahara 1260°, consisting of a half turn off the springboard onto the vault table and 3 and 1/2 twist front somersault technique and put his signature of Yang-2 on this technique. This technique, being allowed D-score of 6.4, was first performed at the Korea Cup 2014 successfully as the Yang-2 vault.

Park and Song (2012) investigated Yang-1 vault in depth previously showing a faster CM horizontal velocity was the important factor to successful vault. However, no research on Tsukahara 1260° (Yang-2) was performed previously. This study was a single-subject study and was purposed to compare the kinematics of Tsukahara 1260° (Yang-2) with that of Yang-1 at the major moments of vaults. Results of this study would be useful to find the difficulty of Tsukahara 1260° and to facilitate the understanding of Tsukahara 1260° in skill acquisition.

METHODS: Yang Hak-Seon, a gold medallist of 2012 Summer Olympic Games, participated in this study. His age, height, and mass were 23 years, 160 cm, and 52 kg, respectively. Motion capture system, consisting of fourteen cameras (Osprey® and Rapter-E®, Motion Analysis Corporation, Santa Rosa, CA, USA), were used to measure Tsukahara 1260° vault with the sampling rate of 200 Hz. Nineteen reflective markers were placed on 28 major anatomical points of 15 body segments (Figure 1).

Figure 1: Experimental set-up and locations of 28 reflective markers.

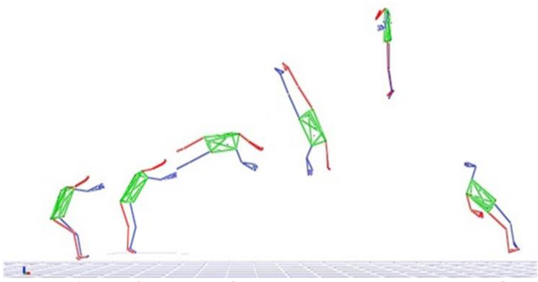

Figure 2: Event definition in Yang-1 vault and Tsukahara 1260° (Yang-2) vault.

Yang performed twice of Tsukahas 1260° (Yang-2) vault during a practice session for domestic championship. Collected marker data passed through Butterworth low-pass filter having a cutoff frequency of 8 Hz. The location of the center of mass (CM) was calculated according to de Leva (1996)'s table. Trunk twist angle, defined as the projection angle of the shoulder line to horizontal plane, and its angular velocity were calculated at Matlab® 2009 (MathWorks, Natick, MA, USA).
The whole procedure of vault was divided into six events such as the springboard touchdown (E1), the springboard takeoff (E2), the vault table touchdown (E3), the vault table takeoff (E4), and the peak CM vertical height (E5), and the landing (E6) (Figure 2). Results of Tsukahara 1260° (Yang-2) vault of this study were compared with those of Yang-1 study (Park & Song, 2012). Due to insufficient trials of a single subject, simple comparison of mean and standard deviation were only executed.

RESULTS: The data of Yang-1 were based on Park and Song (2012) of three trials. The comparison of CM linear velocities of Yang-2 vault with those of Yang-1 vault was shown in Table 1. Results indicated that the CM horizontal and vertical velocities at the springboard touchdown (E1) and the springboard takeoff (E2) were slower in Yang-2 than in Yang-1. The differences in linear velocities between two techniques (Yang-2 – Yang-1) were reduced at the vault table touchdown (E3) and the vault table takeoff (E4). The CM horizontal velocities of Yang-2 were faster than those of Yang-1 at the vault table touchdown (E3) and the vault table takeoff (E4), while the CM vertical velocities of Yang-2 vault were still slower than those of Yang-1 vault.

Table 1
Comparison of Linear Velocity of Center of Mass (CM) (mean±*S.D.*)

	Horizontal velocity of CM			Vertical velocity of CM (m/s)		
Event #	Yang-1 (Park & Song, 2012)	Yang-2	Difference (Yang-2 – Yang-1)	Yang-1 (Park & Song, 2012)	Yang-2	Difference (Yang-2 – Yang-1)
E1	7.72±0.11	7.53±0.18	-0.19	0.08±0.15	-0.65±0.32	-0.73
E2	5.78±0.16	5.48±0.21	-0.30	3.80±0.32	3.12±0.32	-0.68
E3	5.08±0.06	5.12±0.01	0.04	3.75±0.10	3.65±0.16	-0.10
E4	2.74±0.07	3.55±0.16	0.81	3.96±0.02	3.84±0.11	-0.12

Regarding trunk twist motion, Yang-2 turned more than Yang-1 at the landing (about 199.90°, Table 2). The differences in trunk twist angle between two techniques were significantly different. The changes in trunk twist angle during the vault contact (E3 to E4) were 4.00° for Yang-1 vault and 44.98° for Yang-2 vault.

The angular velocities of trunk twist were different between two techniques as well. Yang-2 vault indicated higher angular velocity at the vault table takeoff (E4) and the peak CM vertical height (E5), while those were very similar at the landing (E6). The difference in angular velocity between two techniques was larger at the peak CM vertical height (E5, 149.08°/s) than at the vault table takeoff (E4, 66.19°/s) and at the landing (E6, -1.12°/s). Regarding the contact time of the vault table (E3 – E4), two techniques showed similar periods such as 0.175 s and 0.17 s for Yang-1 and Yang-1 vaults, respectively.

Table 2
Comparison of Trunk Rotation Motion (mean±*S.D.*)

Variable	Event #	Yang-1 (Park & Song, 2012)	Yang-2	Difference (Yang-2 – Yang-1)
Trunk Twist Angle (°)	E3	-13.00±3.61	10.79±0.81	23.79
	E4	-9.00±7.00	55.77±4.46	64.77
	E5	218.67±23.08	377.31±0.86	158.64
	E6	1049.67±11.02	1249.57±3.63	199.90
Trunk Twist Angular Velocity (°/s)	E4	-103.00±86.54	-36.81±10.91	66.19
	E5	1217.00±117.46	1366.08±19.86	149.08
	E6	487.00±99.14	485.88±6.64	-1.12

DISCUSSION: The study illustrated kinematic differences between Yang-1 (handspring triple twist front somersault) and Tsukahara 1260° (Yang-2) vaults. Data of Yang-1 vault was based on Park and Song (2012)'s study.

Kinematically the faster CM vertical velocity is very important for successful vaulting technique from the perspective of projectile motion. Takei (1998, 2007) insisted the faster vertical velocity as the most important contributor to successful vaults. However, Yang-2 vault indicated a slower CM vertical velocity than Yang-1 vault from the springboard touchdown to the vault table takeoff. In addition, the faster CM horizontal velocity is crucial to enhance the CM vertical velocity (Im, 2004; Park & Song, 2012). Yang-2 vault demonstrated slower velocities before the vault table touchdown.

Nonetheless, Yang-2 revealed a larger trunk twist angle and its faster angular velocity than Yang-1 vault at the vault table takeoff and thereafter. This difference could result from the difference in techniques between two vaults. Yang-1 uses a handspring requiring a simultaneous touchdown of both hands on the vault table, while Yang-2 requires a sequential touchdown of the hands due to a half turn off the springboard onto the vault table. People could consider that Yang-2 vault seems much difficult than Yang-1 vault as a result of more twisted angle (more than 180°) in the air and lateral approach to vault table.

However, Yang-2 vault could have an advantage of angular momentum before the vault table touchdown because it approached the vault table with initial angular momentum due to a half turn off the springboard. In addition, a sequential touchdown of the hands, such as the left first and the right last, could facilitate angular momentum positively since the left hand could have a role of a brake and the right have did an accelerator associated with the vault table. This initial angular momentum facilitated the trunk twist angle to 44.98° increase at the moment of the vault table takeoff and its angular velocity to 1366.08±19.86°/s at the peak CM vertical height. However, Yang-1 vault had a difficulty in creating the angular momentum during the vault table contact because of front approach and a simultaneous touchdown of both hands.

CONCLUSION: This study identified the differences between Yang-1 and Yang-2 vaults kinematically. From the perspective of linear kinematic, Yang-1 vault was superior to Yang-2 vault. However, Yang-2 vault revealed superior angular kinematic to Yang-1 vault showing more trunk twist angle (a 3 and 1/2 twist) and its faster angular velocity during the airborne. According to the characteristics of each vault technique, the Yang-2 vault could have advantages of increasing angular motion than Yang-1 vault as a result of a half turn off the springboard onto the vault table and a sequential touchdown of the hands.

REFERENCES:

De Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics*, 9, 1223-1230.

Im, K.C. (2004). Biomechanical analysis of Tsukahara vault with double Salto backward piked. *Korean Journal of Sport Biomechanics*, 14, 135-147.

Park, J.-H. & Song, J.-H. (2012). The kinematic analysis of YANG Hak Seon vault. *Korean Journal of Sport Sciences,* 23, 702-717.

Takei, Y. (1998). Three-dimensional analysis of handspring with full turn vault: Deterministic model, coaches's beliefs, and judges' scores. *Journal of Applied Biomechanics*, 14, 190-210.

Takei, Y. (2007). The Roche vault performed by elite gymnasts: Somersaulting technique, deterministic model and judge's scores. *Journal of Applied Biomechanics*, 23, 1-11.