KINEMATICS OF THE SPRINGBOARD PHASE IN YURCHENKO-STYLE VAULTS

Gabriella Penitente, Franco Merni, Silvia Fantozzi, Nino Perretta*

Faculty of Exercise and Sports Science of Bologna, Italy

The object of this study is the kinematics analysis of the center of mass (COM) in the springboard phase of the Yurchenko-style vault performed by 14 female gymnasts during the 2006 Italian Championship for Clubs. The purpose was to widen the biomechanics knowledge about this phase. Temporal, horizontal and vertical spatial, horizontal and vertical velocity and body's angle parameters were estimated. A representative kinematics analysis of the Yurchenko's springboard phase was compiled based on these parameters. The results indicated that the gymnasts use the board to avoid a large decrease in the COM horizontal velocity and increase their COM vertical velocity. These were realizing by a great body's angle at the board impact, reducing the amount of the downward motion in the gathering and maximizing the successive upward lift of the COM.

KEY WORDS: Yurchenko vault, springboard phase, gymnastics.

INTRODUCTION:

In a Yurchenko vault after the running approach the gymnast executes a round-off onto the springboard and a back handspring onto the vaulting table (Fig.1). Then she performs somersault, which may range in difficulty from a simple single tuck to a triple twist layout before landing with the feet on the mat. All vaults with these features are classified as a "Yurchenko-style" vault (YU) in the Code of Points by the Federation Internationale de Gymnastique (FIG). The present study is focused on the Yurchenko's springboard phase (YUSB). In this type of vault, the YUSB results to be particularly complex for the accuracy needed to perform a "blind entry" from the round-off instead of a frontal entry from running and hurdle, as in the other families of vaults. The effectiveness of this phase outlines the uppermost limits of what the gymnast can attain during the successive phases. Here the kinetic energy generated during the round-off should be transformed into appropriate linear velocity and rotary movement. From two recent reviews of the literature by Prassas (2006) et al and Sands (2003), there are no studies concerning specifically the YUSB. However, from the studies carried out so far on different types of YU (Nelson 1985, Know 1990, Koh 2003,Ragheb 1988, Fortney 1989), it is possible to have some information regarding YU temporal duration both horizontal and vertical velocities of the center of mass (COM) at the impact on the board (BIMP) and at the board take-off (BTKO). To overcome the lack of information regarding the YUSB biomechanics, this analysis includes the COM kinematics variables that define this phase. Therefore, the aim of the present study was to increase the knowledge about the YUSB. In addition to the temporal and velocity data previously mentioned, the horizontal and vertical displacement of the COM and the body's angle have been also quantified.

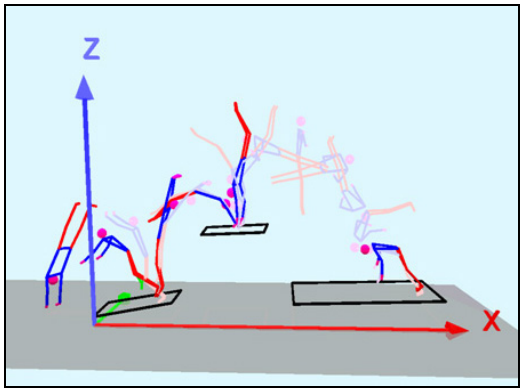

Figure 1 Yurchenko-style vault

METHOD:

Data Collection: 14 YU performed during a women team competition of the 2006 Italian Championship for Clubs were filmed for 3d motion analysis. The vaults analyzed were performed by 14 elite gymnasts. Three high-speed synchronized cameras (BASLER 610, 3CCD, 1Mpixel) with the angle between their optical axes being approximately 120° (Fig.2) filming at a nominal rate of 100 Hz were used. Each vaulter's performance recorded includes the following phases: snap-down phase of the round-off, springboard (SB), preflight, table contact, postflight and landing. A cube calibration structure comprising 8 markers placed in known locations and spanning a volume measuring 1m x 1,10m x 1,10m was positioned in front of the table instead of the springboard. The orientation of the 3d coordinate system was with the x-axis aligned along the runway and the z-axis aligned vertically.

Data analysis: For each performance approximately 50 frames of the movies were digitized with the aid of the SIMI Motion System software. These frames included the gymnast's position at BIMP and BTKO. Nineteen body points (head, tip of the noise, neck, shoulders, elbows, wrists, hands, hips, knees, ankles, feet) defining a 14-segment model of the human body were manually digitized for each frame. Any errors in the digitizing were corrected by redigitization. The location of the COM was computed using the segmental mass proportion and segmental COM location data of Dempster (1955).
The statistical parameters used were mean values (MV), standard deviation (SD) and variability coefficient (VC).

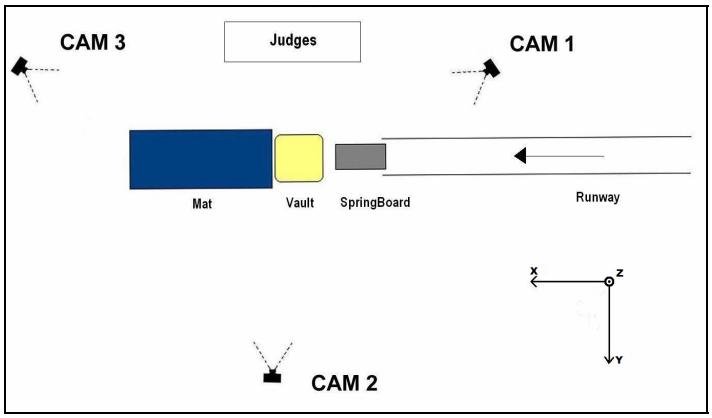

Figure 2 Camera set up

RESULTS:

Spatial-temporal data: The temporal data of the YUSB were expressed in seconds. The spatial data were analyzed in terms of COM horizontal movement (X) during the whole YUSB. To analyze the COM vertical shifting (Z) (Fig. 3) properly we have divided the YUSB in two sub-phases: the gathering phase (GHT) and the pushing phase (PSH). The first one starts at the BIMP and ends at the lowest point reached by the COM; the second one starts at the COM's lowest point and ends at the BTKO (Tab. 1).

Table 1 Time, Horizontal and Vertical space

	Time	Space X	Space Z	
	TOT [sec]	TOT [m]	GTH [m]	PSH [m]
MIN	0,14	0,58	-0,03	-0,29
MAX	0,17	0,82	-0,01	0,35
MEAN	0,15	0,67	-0,02	0,26
SD	0,01	0,08	0,01	0,16
CV (%)	6,9	11,8	39,2	61,8

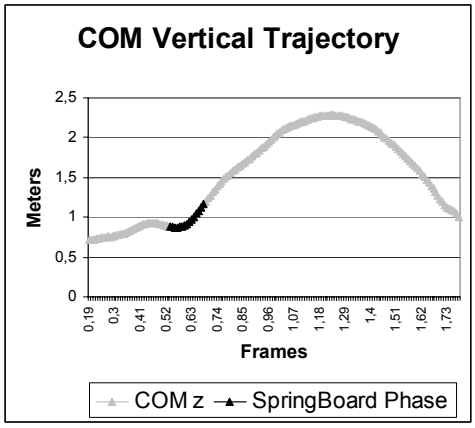

Figure 3 COM vertical shifting

COM velocities data: Velocity values were calculated by differentiating the displacement of the COM. They were measured at the BIMP and BTKO frames and were expressed in m/sec (Tab. 2).

Table 2 COM Horizontal and Vertical Velocities

	Velocity X [m/s]		Velocity Z [m/s]	
	IMP	TKO	IMP	TKO
MIN	4,39	3,22	-0,99	3,47
MAX	6,03	4,61	-0,35	4,00
MEAN	5,27	3,90	-0,72	3,74
SD	0,58	0,35	0,154	0,15
CV(%)	10,9	8,9	21,4	4,0

Body's angle: The body's angle was defined as the angle between the horizontal line and the line passing through the COM and the toe at the BIMP and BTKO frames (Fig 4). It was measured counter clockwise (as a positive angle). The values of the body's angle expressed in degree were reported in Table 3.

Table 3 Body's angles

	Body's Angle [°]	
	IMP	TKO
MIN	-67	81
MAX	-58	89
MEAN	-61	84
SD	3	2
CV(%)	4	3

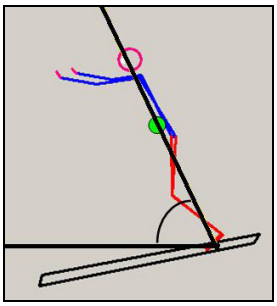

Figure 4 Body's angle

DISCUSSION:

From the temporal analysis of the YUSB it was observed that the mean time spent on the board was 0,15 sec (SD 0,01; VC 6,9%). This value was very similar with those found in the literature (Nelson 0,15 sec; Know 0,14 sec; Raghed 0, 16 sec; Fortney 0,16sec).
The average horizontal space covered by the COM on the board was 0,67m (SD 0,08; CV 11,8%). Relating the data of the horizontal displacement with the temporal data it has been clear that the COM continues moving forward very quickly.

Studying the COM vertical shifting data, it was possible to understand the downward and upward shift of the COM during the YUSB. The BIMP was followed by a light decrease in height of the COM (MV -0,02 m) as the board deflected. This represents the gathering phase on the board and was characterized by negative values because of the downward movement. During the PSH the vertical height of the COM increases (MV 0,26 m) as the gymnast accelerated upward.
The gymnasts impacted the board with an average horizontal velocity of 5,27 m/s (SD 0,58; VC 10,9%) and an average downward velocity of –0,72 m/s (SD 0,15; VC 21,4%) as shown in Table 2. The component velocities results approximate those in the literature (Nelson Vx = 5,32 m/s; Vz = -0,27 m/s. Know Vx = 5,14 m/s; Vz = -0,17 m/s. Raghed Vx = 5,08 m/s; Vz = -0,36 m/s). From a comparison with the literature, minor differences have arisen, they may depend on two factors. On the one hand, the substitution operated by FIG in 2001 of the old vault apparatus, on which have been conducted the previously studies, with the new table vault. On the other, the evolution of the board from a purely wooden structure to fibreglass, wood and steel with integrated coil springs.
The COM horizontal velocity decreased in average by 1,37 m/s during the YUSB. On the contrary COM vertical velocity resulted increased by an average of 4,46 m/s at the same time. The mean horizontal velocity variation during the YUSB reported in the literature is 1,28 m/s. The difference between the founded data and those of the literature is only 0,09 m/sec. Instead, the mean vertical velocity increase is 3,78 m/s. The difference in vertical velocity variation between the present study and previous investigations is more evident (0,72 m/s). The mean body's angle (Tab 3) at the BIMP was nearly 60° (DS 2; VC 2%). At the BTKO it was close to 90° (MV 84°; SD 2; VC 3%).

CONCLUSION:

The results in the present study may be used to design a first representative kinematics analysis of the female YUSB technique. The gymnasts were capable of an effective use of the board in fact all the participants at the competition executed their vault successfully. The biomechanical strategy used by gymnasts to gain advantage from the YUSB was to avoid a large decrease in the COM horizontal velocity and increase their COM vertical velocity. These were realizing by a great body's angle at the BIMP, reducing the amount of the downward motion in the gathering and maximizing the successive upward vertical lift of the COM. Many data find agree with those of the literature. The differences are relative to the vertical velocity but in the previous studies they were found on the old springboard.

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