

ON-BOARD AND PRE-FLIGHT MECHANICAL MODEL OF YURCHENKO ONE TWIST ON VAULT: IMPLICATIONS FOR PERFORMANCE

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The aim of this study was to point out the biomechanical explanation of the judges' detection of scores relative to the on-board and pre-flight phases of the Yurchenko vault with one twist on (table). In an attempt to identify the weakness of technique and then to diagnose the likely causes of a poor performance, an extensive analysis was undertaken using a deterministic model. The 4 female gymnasts performing YU vault one twist on during the 2006 Italian Championship for Clubs were filmed by three cameras operating at 100Hz. Spearman's correlation coefficient was used to establish the strength of the relationship between the mechanical variables of the model and the judges' detection of points. Significant correlations indicated that the loss of credit depended mostly on angular variables. Firstly, low angular velocity of the center of mass (CM) at the impact of the board, then the small angular displacement of CM and high shoulder angular velocity produced on board and finally, a smaller hip extension and a larger shoulders extension at the take off from the board. In addition, other vertical variables determined a worst result: the lack of height of the CM at takeoff from the board, the decreased displacement of the CM on the board and the loss of the vertical velocity on the board.

KEY WORDS: Yurchenko vault, mechanical model, gymnastics

INTRODUCTION: In the Yurchenko (YU) family vaults – from round off entry – the on-board and pre-flight are both two critical phases because of the transitional action in which the gymnast's orientation change from forward to backward. The YU one twist on (table) is the most advanced evolution in this family of vaults. It is characterized by a full twist in the pre-flight that can negatively affect the linear velocity and angular momentum during the successive phases of the handspring on the table and the post-flight. Because of this, and the high risk of scores deductions, only few skilled gymnasts perform YU one twist on vaults in competition. In fact, the scoring system introduced in the 2005 provides that during the vault tournament gymnasts are awarded scores by two panels of judges. The first one is the difficulty score (D-score) represented by the specific value assigned to every vault in the Code of Points. The D-score is the same for every gymnast performing a similar vault. The second panel is the execution score (E-score) that evaluates the quality of the performance and this is the most important one. The base E-score is 10 and judges deduct points for errors in form, technique, execution and landing. Most of the studies conducted so far on YU (Nelson, Gross & Street, 1985; Elliott & Mitchell, 1991; Known et al, 1990; Koh, Jennings & Elliott 2003; Koh et al 2003) provided a biomechanical profile of this kind of vault performed on the old horse. The results carried out from several studies on vault (Koh, Jennings and Elliott, 2003; Know, Fortney & Shin, 1990; Penitente et al 2007) revealed that faults occurred in the latter phase of the skill are caused by the poor performance of the earlier phases. In particular, the landing is influenced by the post-flight. This in turn, is governed by the pre-flight and the on-board phases. The aim of the present study is to determine the weakness of performance and then to diagnose the likely causes of poor execution of the on board and pre-flight phases of the YU vault one twist on. The analysis was undertaken using a deterministic model arranged on the handspring vault model, developed by Takei (1998) and based on the method of Hay and Reid (1988).

METHODS: Data Collection: The 4 Yurchenkos performed by elite gymnasts during a women team competition in the 2006 Italian Championship for Clubs, were recorded for 3D motion analysis. Three high-speed synchronized cameras (BASLER 610, 3CCD, 1Mpixel) were used, each filming at a nominal rate of 100Hz, with the angle between their optical axes set at approximately 120°. The x-axis of the 3D reference system was directed along the

runway, the z-axis was orthogonal to the floor, and the y axis oriented orthogonal to the x-z plane. Each trial included the following phases: snap-down phase of the round-off, on-board and pre-flight. The SIMI Motion System software was used to digitize approximately 50 frames of the movies from the impact on the board (BIMP) to the take-off from the table. The gymnasts' body was characterized by a 14-segment model identified by nineteen body points (head centre, tip of the nose, neck (7th C), shoulders, elbows, wrists, hands (3rd finger base), hips, knees, ankles, feet tip). The data were filtered with a low-pass second-order filter with a cut-off of 6Hz. The location of the center of mass (CM) was computed using the anthropometric parameters of Dempster (1955).

Data Analysis: Based on Takei's model (1998) and Hay and Reid's method (1988), a six-level deterministic model was developed. This included the linear and angular variables crucial for the on-board and pre-flight phases of the vault (Figure 1). The model depicted was used to analyze the correlations (Spearman's rank correlation coefficient) between the selected mechanical variables and the deduction of E-scores assigned by judges. In order to analyze the good form and technique in the early phases of the movement the deduction assigned for errors in landing have not been considered. Under the supervision of a certified international judge, after an accurate review of the movies, the landing point deductions have been quantified and subtract from the E-score awarded. The partial E-score deductions obtained has been used for the correlation analysis.

RESULTS: Figure 1 depicts the correlations of pre-flight factors with the partial E-score points deducted by judges. The thickness of the lines linking variables indicates the magnitude of the relationship. The significant correlations are indicated by bold boxes.

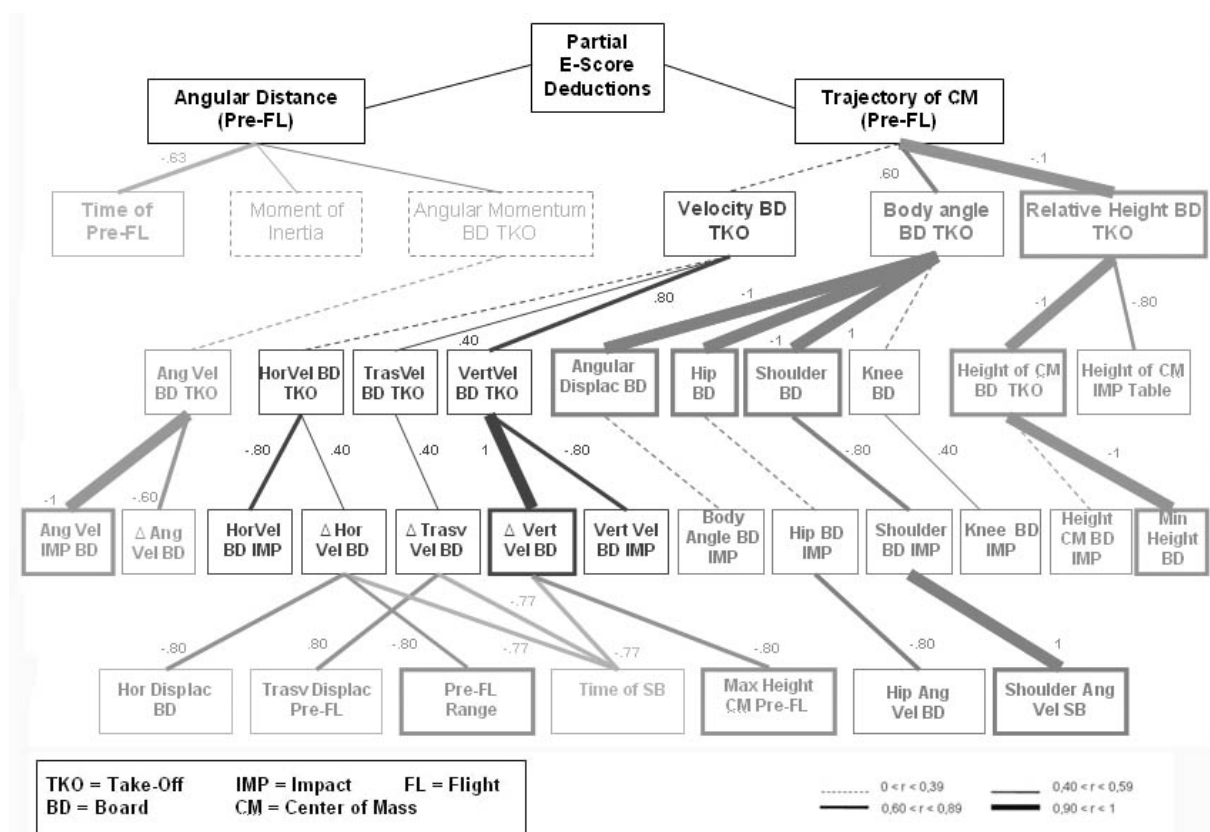


Figure 1 – Deterministic model of on board and pre-flight phases of the Yurchenco one twist on vault

In order to detect the influence of the mechanical quality relative to the early phases of the skill on the overall performance of the YU one twist on vault two variables were identified in the second level of the model; the angular distance and the trajectory of the CM during the

pre-flight. Among the variables determinant for the angular displacement of the CM only the angular velocity of the CM at the impact of the board, located at the 5th level of the model, was significantly correlated with the partial deductions assigned by the judges ($\rho=-1$). This negative correlation meant that the decrease of the angular velocity at the impact with the board increase the judges' penalty. Regarding the variables that determine the trajectory of the pre-flight, the score is negatively correlated between the vertical displacement achieved by the CM at the instant of take off from the board ($\rho=-1$) (3rd and 4th level) and during the board phase ($\rho=-1$) (5th level). This meant that these two variables were equally important because they accounted for similar variances with the judges' deductions. The less relative height of the CM at the take off from the board and the decreased displacement of the CM during the board phase increased the penalties. The reduction of the vertical velocity on the board was positively correlated with the score deduction, so the loss of velocity in this phase determined a worst score. The significant correlations found with the segmental angular variables in the 3rd level of the model revealed that a reduced hip angle ($\rho=-1$) and a larger shoulder angle ($\rho=1$) at the take off from the board determined a lower score. In addition, the angular velocity of the shoulder on the board was positively correlated with the score deductions ($\rho=1$). The correlation of the angular displacement of the body on the board with the score deductions in the 3rd level, was significant ($\rho=-1$). This meant that increased angular displacement on the board decreases the penalty assigned by judges.

DISCUSSION: The results from this study represented an analysis of the kinematic faults which occurred in the earlier phase of the YU one twist on vault. The deterministic model developed shows how a relatively large number of linear and angular variables during the on board and pre-flight phases can explain the penalty assigned by judges in competition. For the vault analyzed in the present study, the mechanical objectives of the on board phase is to generate the optimal pattern between lift, travel and biaxial rotation (somersault and twisting) in the pre-flight phase. The model displays the mutually interdependence between these three requirements and overviews the effect of the linear variables upon the angular ones and vice versa. The characteristics of the take-off from the board appeared to be very similar to those of the full twist backward somersault on the floor (George, 1980) in which gymnasts used an on ground twist technique to initiate the rotation about the longitudinal axis. The model showed that a too small blocking angle of the body, associated with a poor extension of the hip and an excessive extension of the shoulder at take off, were causes of deduction of points. Accumulation of these angular factors leads the gymnasts to over-initiate the twist on the board. This is caused by twisting the upper body about the lower body too early on the board creating an extended arched body shape at the take off. The high magnitude of the correlations of most of the variables in the last level of the model suggests that the gymnasts should spend more time on the board. This enables to travel through a larger blocking angle, to initiate the twist as later as possible and to increase the impulse. Developing a large angular displacement on the board would also achieve a higher quantity of lateral axis rotation and increase the quality of both the somersaulting and the travelling action. It was possible to detect that, for the YU one full twist on vault a too great angular velocity of the shoulder in the somersault direction affected the performance negatively, contrary to the traditional strategy used to improve the backward somersault rotation on board where a rapid swing of the upper body was desired to enhance the angular momentum (Koh et al 2003 and 2004). This is because, in the YU one full twist the arms are more involved in the generation of the longitudinal rotation. The somersault's momentum has to be generated developing a technically perfect blocking angle of the body instead of freely throwing the arms backwards. In comparison with other studies conducted on the YU vaults (Takei, 1998) that identified the maintenance of the horizontal velocity and the gain of the vertical velocity of the take off board as a crucial performance factor, the present study showed some dissimilarity. The horizontal component appeared to have just a marginal rule to better the score; in fact no correlations between the horizontal variables and the penalties were significant. On the other hands, the vertical component, both in terms of displacement and velocity of the CM, appeared to be an important factor for a successful performance of the YU one twist on vault.

The results show that the gymnasts can improve their score by, minimizing the descendent motion on the board and enhancing the vertical velocity during the on board phase, in order to achieve the desired lift of the CM during the pre-flight.

CONCLUSION: In conclusion, the deterministic model of the YU one full twist on vault drawn in the present study provides considerable evidence that the pre-flight full twisted phase makes this YU vault very hard to perfect score during competition. The bi-axial rotation in the early phase of the vault leads gymnasts to make kinematics faults that affected the general performance causing points deduction during later stages of the vault. The loss of credit resulted, is associated with an erroneous body shape and a low development of the vertical motion during the on board phase. These disadvantageous kinematic faults affected first, the optimal achievement of the pre-flight multi-tasks (lift, travel and rotate) thus, the successive phases and the general performance of the vault. In addition, this study has highlighted the importance of the different rule of the arms action in the generation of the angular momentum on the board between this kind of YU vault and the traditional YU vault style previously analyzed.

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