KINEMATIC ANALYSIS OF THE BACKWARD UPRISE AND FORWARD SALTO TO SUPPORT ON PARALLEL BARS: A PILOT STUDY

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ABSTRACT
Technical execution is a key factor in the performance of artistic gymnasts. The parallel bars, one of the six apparatuses in men's artistic gymnastics, require routines to include elements from four structural groups: (1) elements starting from an upper arm position, (2) support or through support on both bars, (3) long swings in hang on one or two bars, and (4) underswings and dismounts. This pilot study investigates the mechanics of the backward uprise and forward salto to support an element from Group I that holds high compositional and technical value.
A 2D kinematic analysis was conducted using video footage recorded at the National Sports Academy in Sofia. Motion was digitized with SkillSpector (v1.3.2) using Direct Linear Transformation. Ten anatomical landmarks were tracked, and the movement was analyzed with reference to hip, shoulder, and arm actions.
The results demonstrated that coordinated hip extension created two distinct impulses—one before and one after the vertical—while arm push contributed to an effective release. The gymnast's center of gravity (CG) followed a forward and upward trajectory, enabling secure regrasping and stable support.
These findings indicate that hip extension, swing amplitude, and active arm push are critical for the successful execution of this element. The study highlights technical priorities that can support coaches and athletes in learning and integrating this skill into competitive routines.

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INTRODUCTION

The technical execution of gymnastics elements plays a fundamental role in the progression and performance level of artistic gymnastics. Among the six apparatuses in men's artistic gymnastics, the parallel bars offer a unique set of biomechanical challenges due to their symmetrical structure and the combination of swing and strength elements required. The historical progression and technological development of the apparatus have also influenced the evolution of skill complexity and performance opportunities (Bábela, 2025). Kinematic analysis has emerged as a key method for understanding and optimizing movement techniques, offering valuable insights for more effective and economical coaching and skill acquisition (Heng, 2007; Hiley & Yeadon, 2007; Takei, 1998; Brüggemann et al., 1994).

A number of studies have contributed to our understanding of movement mechanics on the apparatus. Linge et al. (2006) developed models of movement on the parallel bars, while Prassas and Ariel (2005), along with earlier works by Prassas (1994), investigated the biomechanics of giant swings and back tosses. Similarly, Tsuchiya et al. (2004) and Prassas et al. (2004) examined key mechanical parameters of these fundamental skills. Gervais and Dunn (2003) focused on the double back salto dismount, highlighting release dynamics and flight phase mechanics. Comparative analyses have also been employed to study variations of similar elements; for instance, Kolar et al. (2002) compared biomechanical characteristics of support backward swings versus support swings leading into a 1¼ straddled piked forward salto. More recent studies have also examined the kinematics of newly introduced elements on parallel bars, such as the analysis of the 'Dimic' element and its comparison with the "Bilozerchev" (Kolar et al., 2017).

Over time, elite gymnasts have continually aimed to increase the difficulty of their routines by incorporating more complex and dynamic elements, especially among the eight counted for the difficulty score. The initial phases of routines—particularly those that begin in the upper arm or support position—play a critical role in setting up the momentum and spatial configuration required for complex flight elements.

A noteworthy development in this context is the competitive performance of the backward uprise and forward salto to support on parallel bars, which has been included in the Code of Points as a "D" value element in Group I (#52, EG I). Although the element had been performed previously, it has not yet been the subject of targeted kinematic analysis, despite being a common component in the routines of many elite gymnasts. Importantly, it serves as a logical and technical precursor to the element analyzed in our previous study — the backward uprise and 5/4 straddled forward salto to hang (Yanev & Stoimenov, 2022) — providing a fundamental basis for understanding the mechanical structure and preparatory phases required for more advanced variations.

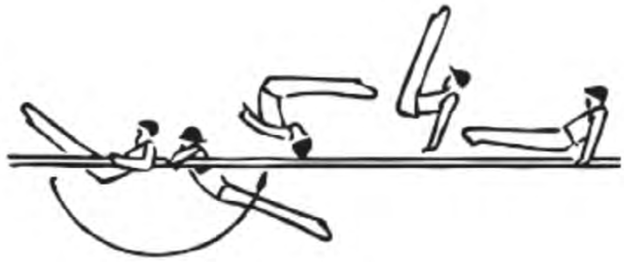

Figure 1. *Backward uprise and forward salto to support on parallel bars.*

The present study aims to address this gap by analyzing the movement mechanics of the backward uprise and forward salto to support. By applying 2D video-based kinematic analysis of training footage recorded at the Bulgarian National Sports Academy, the study explores the key biomechanical phases and release conditions that enable the successful execution of this compositionally significant element.

METHODS

We chose to investigate the element—backward uprise and forward salto to support. The studied performance was recorded with a fixed Samsung video camera, operating at 50 fps, positioned perpendicular to the gymnast's side axis at the level of the swing, in accordance with all biomechanical analysis requirements. 2D video-based data was used to analyze the new element recorded under training conditions at the Bulgarian National Sports Academy training center. The Ariel Performance Analysis System was used for digitizing, and DLT techniques were applied (SkillSpector 2020, version v1.3.2). The space was calibrated with 8 points with previously known coordinates (Figure 2), and the movement was digitized using 10 points (toe, ankle, knee, hip, shoulder, elbow, wrist, finger, chin, and forehead) (Figure 3).

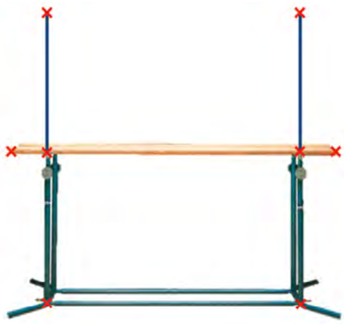

Figure 2. *The space calibration with 10 points.*

Figure 3. *Digitized with 10 points (toe, ankle, knee, hip, shoulder, elbow, wrist, finger, chin, and forehead).*

RESULTS

Through video recording and pedagogical supervision, we identified the best performance to subject for kinematic analysis (Figure 4).

Figure 4. *A sequence of images with mechanical axes and the CG of the backward uprise and 5/4 salto fwd straddled to hang on parallel bars.*

The duration of the element execution is 1,86 sec. The foothold period, during which the preparatory actions for the exercise are performed, is 1,01 sec. The swing is performed for 0,44 sec, and a repeated hold of the apparatus follows. The starting position is picked upper arm support. The exercise starts with active forward and upward unfolding of the body in the pelvis joints and moves the shoulders closer to the wrists. The configuration of the gymnast remains closed until passing the vertical, where the swing is performed and the body stretches. The swing amplitude is 66° in the pelvis joints – Figure 6. The gymnast remains in an open configuration until the end of the support phase. The angle between the pelvis joints is 214°, respectively, as shown in Figure 5.

Figure 5. *Release body configuration during backward uprise and salto fwd to support.*

After releasing the bars, the gymnast initiates an active hip flexion until reaching the highest point of the center of gravity (CG). This moment corresponds to the most piked body position, where the angle between the torso and the thighs is 59°. At this point, the angular velocity of the torso reaches 613 degrees per second. In coordination with the hip flexion, the arms move downward along the sides of the body.

Following the peak height of the CG, the gymnast begins the extension phase. During this phase, angular velocity decreases, allowing for more effective body regrouping in preparation for regrasping the apparatus. The body configuration at the moment of regrasp is still piked, with an angle of 97° between the torso and thighs (Figure 7).

Figure 6. *Swing actions backward, uprise, and salto forward to support.*

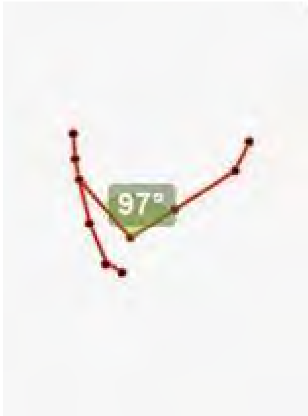

Figure 7. *Regrasp body configuration during backward uprise and salto forward to support.*

DISCUSSION

As we have already specified, the purpose of this study was to explain the mechanics of the backward uprise and forward salto to support Parallel Bars, and to identify how the release conditions were created.

The kinematic analysis of the technical actions revealed that the trajectory of the gymnast's center of gravity (CG) shifts in a forward direction during the flight (non-support) phase of the element. This forward displacement of the CG indicates a well-executed element with sufficient amplitude in the airborne phase. The extended arm position at the moment of regrasping the apparatus, followed by the successful execution of the subsequent skill without technical or judging deductions, further supports this conclusion from both a biomechanical and evaluative standpoint. Based on this observation, we recommend the inclusion of similar swinging actions and transitions from support to non-support phases in training and routine composition. Similar conclusions were reported by Kolar et al. (2017), who analyzed the "Dimic" element on parallel bars and highlighted the role of hip extension and trajectory control in the successful execution of innovative release-regrasp skills. This perspective also corresponds with the broader view of parallel bars development and dynamics (Bábela, 2025) and is complemented by recent findings on dismount strategy preferences (Rodríguez-Redondo et al., 2025). Building on these broader perspectives, our data further indicate that the direction of takeoff in such elements is upward and forward. Following hip flexion, the angular velocity of the torso increases (Figure 8).

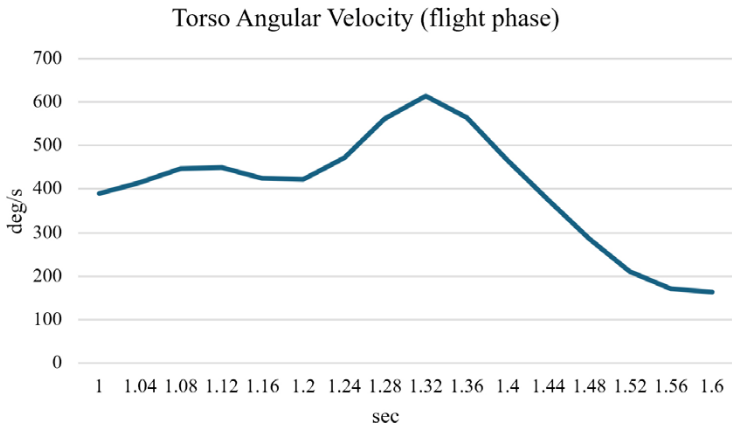

Figure 8. *Torso angular velocity (deg/s) during the non-support phase.*

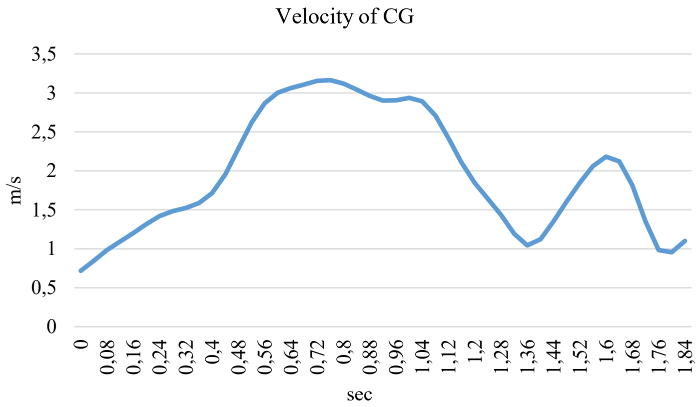

Figure 9. *CG velocity during backward uprise and salto fwd to support.*

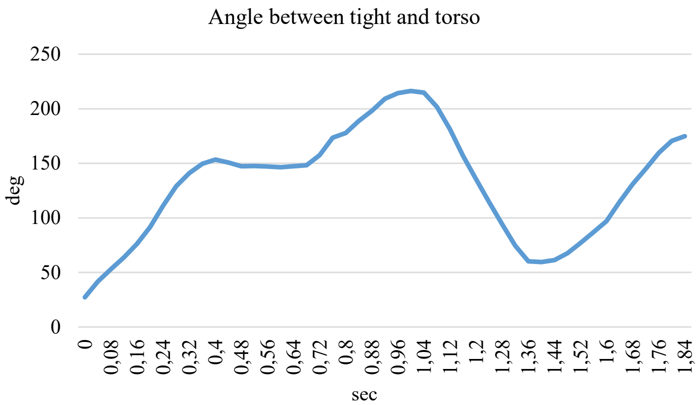

Figure 10. *Angle between the thigh and torso during backward uprise and salto forward to support.*

CONCLUSION

This pilot study examined the biomechanics of the backward uprise and forward salto to support on parallel bars. The kinematic analysis revealed three main findings:

1. Hip extension produced two critical impulses that initiated and controlled the swing.
2. Arm push before release contributed significantly to the forward and upward displacement of the gymnast's CG.

The CG trajectory was optimal for regrasping, supporting effective technical execution without deductions.

The study has some limitations, including the analysis of a single performance, 2D video conditions, and the absence of comparative data. Nevertheless, the results provide valuable insight into the mechanical requirements of the skill.

From a practical standpoint, coaches should emphasize:

- maintaining a closed configuration until vertical,
- generating hip extension with sufficient amplitude, and
- coordinating arm push for secure regrasping.

These recommendations may facilitate the acquisition of the element and prepare gymnasts for more advanced variations in competitive practice.

REFERENCES

Bábela, M., & Seman, F. (2025). The history and technological development of the men's gymnastics apparatus – the parallel bars. *Science of Gymnastics Journal, 17*(2), 199–220. https://doi.org/10.52165/sgj.17.2.199-220

Brüggemann, G. P., Cheetham, P., Alp, Y., & Arampatzis, D. (1994). Olympic scientific projects: Approach to a biomechanical profile of dismounts and release-regrasp skills of the high bar. *Journal of Applied Biomechanics, 10*(3), 291–312. https://doi.org/10.1123/jab.10.3.291

FIG. (2025). *Code of points: Men's artistic gymnastics 2025–2028.* Fédération Internationale de Gymnastique. https://www.gymnastics.sport/publicdir/rules/files/en_1.1%20-%20MAG%20Code%20of%20Points%202025-2028.pdf

Gervais, P., & Dunn, J. (2003). The double back salto dismount from the parallel bars.. *Sports biomechanics, 2*(1). 85–101. https://doi.org/10.1080/14763140308522810

Heng, T. (2007). Kinematical descriptors of circles of short pommel horse in men's artistic gymnastics. *Journal of Biomechanics, 40*(2), S741. https://media.isbweb.org/images/conf/2007/ISB/0089.pdf

Hiley, M., & Yeadon, M. R. (2007). Optimization of backward giant circle technique on the asymmetric bars. *Journal of Applied Biomechanics, 23*(4), 300–308. https://doi.org/10.1123/jab.23.4.300

Kolar, E., Andlovic-Kolar, K., & Štuhec, S. (2002). Comparative analysis of selected biomechanic characteristics between a support backward swing and support swing for the 1¼ straddle-piked forward salto on the parallel bars. *Sports Biomechanics, 1*(1), 69–78. https://doi.org/10.1080/14763140208522787

Kolar, E., Piletić, S., Bedenik, K., Pavletić, S. M., Štuhec, S., & Veličković, S. (2017). Kinematic analysis of the new element "Dimic" and its comparison with "Bilozerchev" on parallel bars. *Science of Gymnastics Journal, 9*(1), 83–96. https://doi.org/10.52165/sgj.9.1.83-96

Linge, S., Hallingstad, O., & Solberg, F. (2006). Modelling the parallel bars in men's artistic gymnastics. *Human Movement Science, 25*(2), 221–237. https://doi.org/10.1016/j.humov.2005.11.008

Prassas, S., Ostarello, J., & Inouye, C. (2004). Giant swings on the parallel bars: A case study. In M. Lamontagne (Ed.), *Proceedings of the XXII International Symposium on Biomechanics in Sports* (p. 133). https://ojs.ub.uni-konstanz.de/cpa/article/view/1255/1177

Prassas, S. (1994). Technique analysis of the back toss on the parallel bars performed by elite gymnasts. In A. Barabas & M. Fabian (Eds.), *Proceedings of the XII International Symposium on Biomechanics in Sports* (pp. 249–251). https://ojs.ub.uni-konstanz.de/cpa/article/view/2563/2413

Prassas, S., & Ariel, G. (2005). Kinematics of giant swings on the parallel bars. In Q. Wang (Ed.), *Proceedings of the XXIII International Symposium on Biomechanics in Sports* (pp. 953–955). https://ojs.ub.uni-konstanz.de/cpa/article/view/1154/1041

Rodríguez-Redondo, Y., Martin-Blázquez, J., & León, K. (2025). What determines the dismount side on parallel bars? *Science of Gymnastics Journal, 17*(2), 221–231. https://doi.org/10.52165/sgj.17.2.221-231

Takei, Y. (1998). Three-dimensional analysis of handspring with full turn vault: Deterministic model, coaches' beliefs, and judges' scores. *Journal of Applied Biomechanics, 14*(2), 190–210. https://doi.org/10.1123/jab.14.2.190

Tsuchiya, J., Murata, K., & Fukunaga, T. (2004). Kinetic analysis of backward giant swing on parallel bars. *International Journal of Sport and Health Science, 2*(1), 211–221. https://doi.org/10.5432/ijshs.2.211

Yanev, I., & Stoimenov, E. (2022). Kinematic analysis of backward uprise and 5/4 salto fwd straddled to hang on parallel bars. In *Proceedings of the International Scientific Congress "Applied Sports Sciences"* (Vol. 2, pp. 92–96). https://doi.org/10.37393/ICASS2022/88

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