KINEMATIC ANALYSIS OF PIKE SOLE CIRCLE BWD THROUGH HANDSTAND WITH FLIGHT TO HANG ON HIGH BAR ON UNEVEN BARS – EDUCATIONAL STUDY

Emil Stoimenov, Iliya Yanev & Veneta Hristova
National Sports Academy "Vassil Levski", Sofia, Bulgaria

ORCID
Emil Stoimenov
https://orcid.org/0000-0003-4767-6916
Iliya Yanev
https://orcid.org/0000-0002-8255-5856
Veneta Hristova
https://orcid.org/0000-0003-4979-6700
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ABSTRACT
The study of sports technique plays a key role in enhancing performance in artistic gymnastics. The flight element from the low bar to the high bar is a mandatory compositional requirement on the uneven bars. The difficulty score on this apparatus is determined by the eight most challenging elements performed during the routine, making the successful execution of complex flight elements essential for achieving high results. This study aims to analyze the key technical aspects of the backward giant circle with handstand position and flight to hang on the high bar, initiated from a toe-on support on the low bar. The subject of the study is the technique of the element, while its object is its kinematic characteristics—specifically, the velocity and angular changes in the major joints. To collect and analyze data, the software SkillSpector version 1.3.2 was used to digitize the movement of key body segments (toes, ankles, knees, hips, shoulders, elbows, wrists, fingers, chin, and forehead). The results indicate a peak velocity of 10 m/s for the gymnast's center of mass, as well as maximum hip flexion during the support phase of the giant circle. The findings suggest that the velocity of the center of mass during the support phase is a critical factor for the successful completion of the element. Based on the analysis, targeted recommendations and a training methodology have been developed to support coaches and educators in optimizing the technical execution of this element in practice.

Keywords: *gymnastics, technique, uneven bars*

INTRODUCTION

Gymnastics technique is a crucial factor in the development of artistic gymnastics and in the performance of gymnasts. The uneven bars are a core apparatus in the women's all-around event. It is the only apparatus in women's artistic gymnastics that involves suspended movements (i.e., hanging apparatus). Studies focused on the kinematic analysis of specific movement types have become increasingly common in artistic gymnastics, especially as the data obtained allows for more rational and efficient training and learning of the analyzed skills (Heng, 2007; Hiley & Yeadon, 2007; Takei, 1998; Brüggemann et al., 1994).

Every gymnastics combination must include elements from four compositional requirement groups, which for the uneven bars are: a flight element from the low bar to the low bar; a flight element on the same bar; grip variation (non-regular, intermediate, or undergrip); and a non-flight element with a minimum of 360° rotation (not from intermediate grip). Takei (1991) devoted a significant portion of his research to the uneven bars apparatus in women's artistic gymnastics. Prassas et al. (2006) examined various types of giant swings during dismounts on parallel bars. Irwin et al. (2014) analyzed the biomechanical evolution of the Tkatchev technique on uneven bars in women's gymnastics. Bradshaw and Hume (2012) investigated biomechanical approaches for identifying and quantifying injury mechanisms and risk factors in women's artistic gymnastics.

Furthermore, many research studies have addressed comparative analyses of similar elements. Kolar et al. (2002) conducted comparative studies of selected biomechanical characteristics between a support swing backward and a support swing into a straddled 1¼ somersault on parallel bars. Gymnasts strive to increase the difficulty of their performed combinations over time by including more complex elements among the eight elements considered for the difficulty score. Due to their complexity and the specificity of their starting position, elements from this structural group on the uneven bars appear to be a decisive factor in determining the difficulty score in competitive routines.

One such element from Group 5—a giant circle in pike position with toe-on support through handstand and flight to hang on the high bar—was successfully performed for value during the European Championships (BUL) in 2014 and was officially assigned a D value (CR V) – see Figure 1.

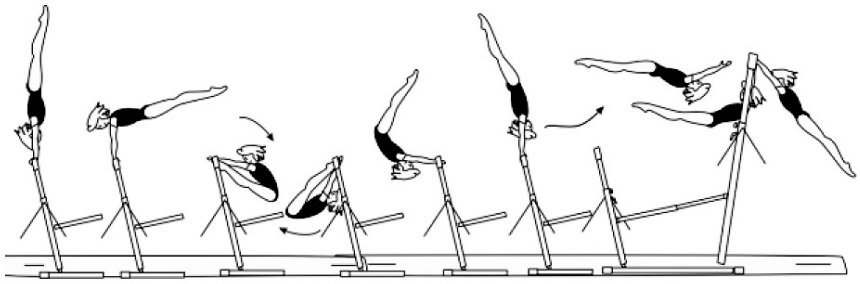

Figure 1. *Pike sole circle bwd through handstand with flight to hang on high bar on uneven bars*

The aim of this study was to explain the technique of performing a toe-on giant circle through a handstand with a flight to the high bar on the uneven bars and to determine how the release conditions are generated. For the analysis of the element, 2D video data from a routine performed at the 2014 European Championships in Sofia were used.

METHODOLOGY

The focus of this research was the toe-on giant circle through handstand with a flight to the high bar performed on the uneven bars. The analyzed routine was recorded using a stationary SONY video camera with a frame rate of 30 frames per second, positioned perpendicular to the gymnast's lateral axis at the height of the uneven bars, in accordance with standard biomechanical analysis requirements. 2D video data from the performance at the 2014 European Championships in Sofia were used for the analysis. The element was digitized using the video-based motion analysis system SkillSpector, version 1.3.2. The data were processed using a digital filter with a frequency of 7 Hz before further calculations were conducted. The measurement space was calibrated using eight reference points with predefined coordinates (Figure 2), and the gymnast's movement was digitized using ten anatomical landmarks corresponding to major joints and the head (toe, ankle, knee, hip, shoulder, elbow, wrist, finger, chin, and forehead) – Figure 3.

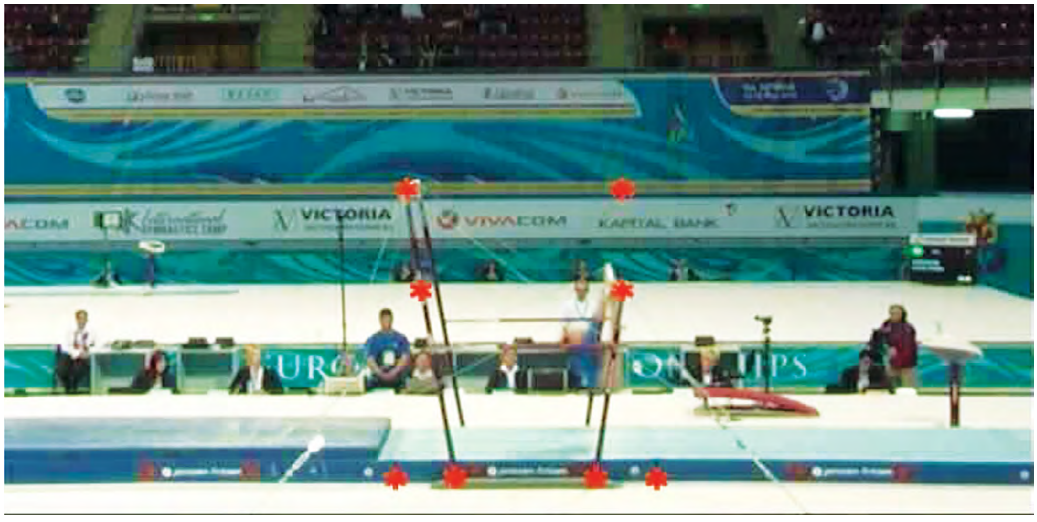

Figure 2. *The space calibration with 8 points.*

Figure 3. *Digitized with 10 points of the main joints and the head. (toe, ankle, knee, pelvis, shoulder, elbow, wrist, finger, chin, and forehead)*

RESULTS

Through video recording and pedagogical observation, the most optimal performance was identified for conducting the kinematic analysis (Figure 4).

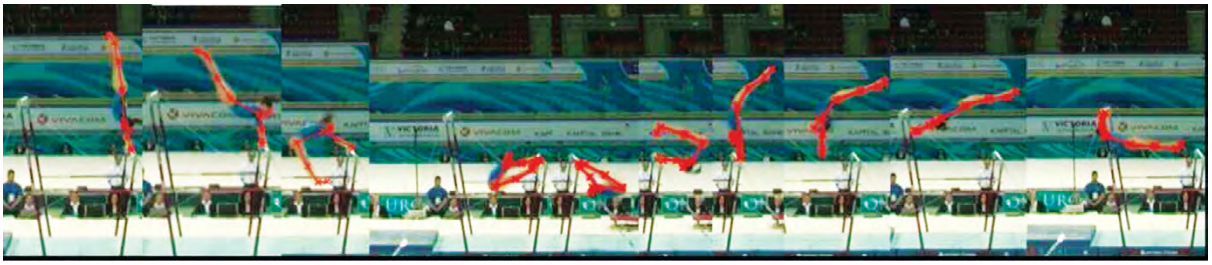

Figure 4. *Pike sole circle bwd through handstand with flight to hang on high bar on uneven bars*

The analyzed element belongs to the fifth structural group of the Women's Artistic Gymnastics Code of Points (FIG WAG COP 2025–2028). According to the Code, its difficulty value is rated as "D" (0.4 points). The skill is a toe-on backward giant circle through a handstand with a flight to hang on the high bar of the uneven bars. The element represents a transition from a support to a non-support position and includes a regrasp of the bar. For clarity of analysis, the skill was conditionally divided into three phases: the preparatory phase, the main phase, and the final phase. The preparatory phase is part of the support phase of the element. The starting position is a handstand, which serves as a transitional posture, followed by a backward push-off from support, accompanied by shoulder flexion and slight hip flexion. After this, the gymnast begins active hip flexion combined with slight shoulder extension. The gymnast's efforts are entirely focused on preparing for toe-on contact with the bar and the transition through hang. In terms of velocity, the speed increases gradually under the influence of gravity, reaching a peak value of 9.8 m/s at the end of the phase. The preparatory phase concludes at the moment of toe contact with the bar, during which the body demonstrates significant hip flexion measured at 37 degrees.

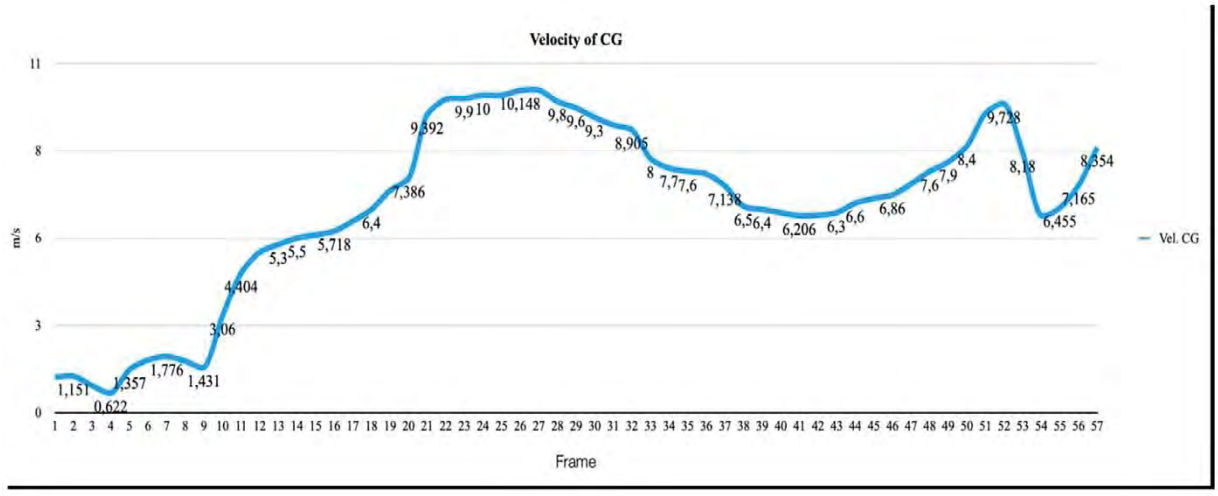

Figure 5. *Velocity of the center of gravity*

The main phase begins with the toe-on contact with the bar, which is a key moment for the successful execution of the element. Ideally, the toe contact should occur as late as possible in order to accumulate maximum velocity. In the analyzed performance, the gymnast places the toes on the bar at frame 24, at an angle of 28 degrees relative to the horizontal axis (Figure 6).

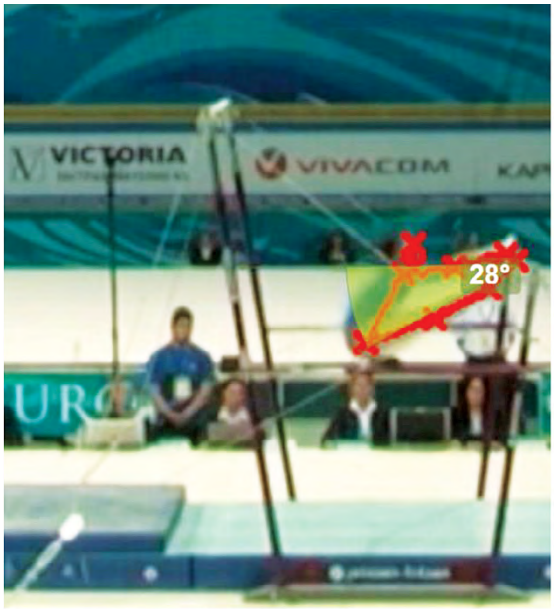

Figure 6. *The gymnast steps on the bar*

During this phase of the element, the gymnast maintains pressure on the front part of the feet, with solid support through the legs and applies significant force with the hands onto the bar. The majority of the rotational movement occurs with the shoulders fully extended, creating the maximum possible radius of rotation. The legs remain tight and together, the abdominal muscles are engaged, and the head is tucked toward the chest. At frame 32, the gymnast initiates body extension through the shoulder and hip joints, combined with an upward lift of the upper back. The release of the feet from the bar occurs at an angle of 12 degrees above the horizontal (Figure 7). At this moment, the velocity of the center of mass during the extension phase reaches 7.1 m/s.

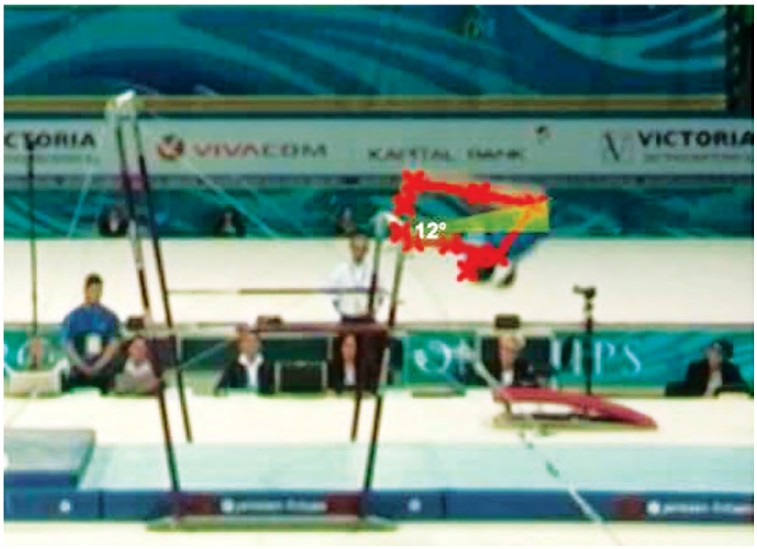

Figure 7. *The separation of the feet from the bar*

After the feet leave the bar, the rapid extension of the body in the shoulder and hip joints continues until full hyperextension is achieved. At frame 40, the gymnast enters the non-support phase, passing over the low bar of the uneven bars. This phase is considered to continue until the center of mass reaches its highest point—at frame 46—after which the gymnast transitions into the final actions required to complete the element.

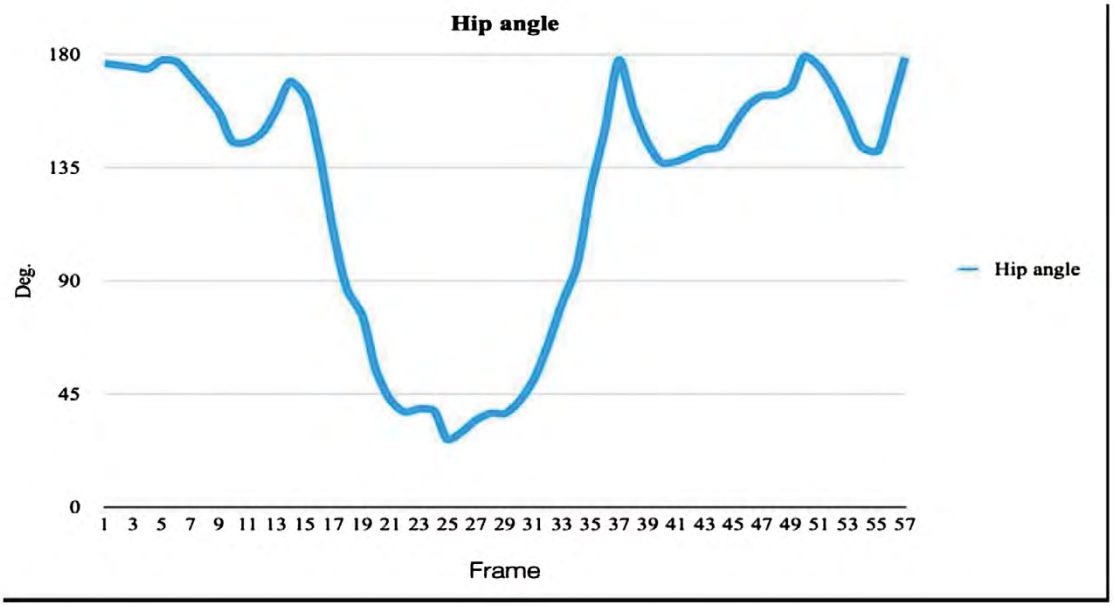

Figure 8. *Hip angle*

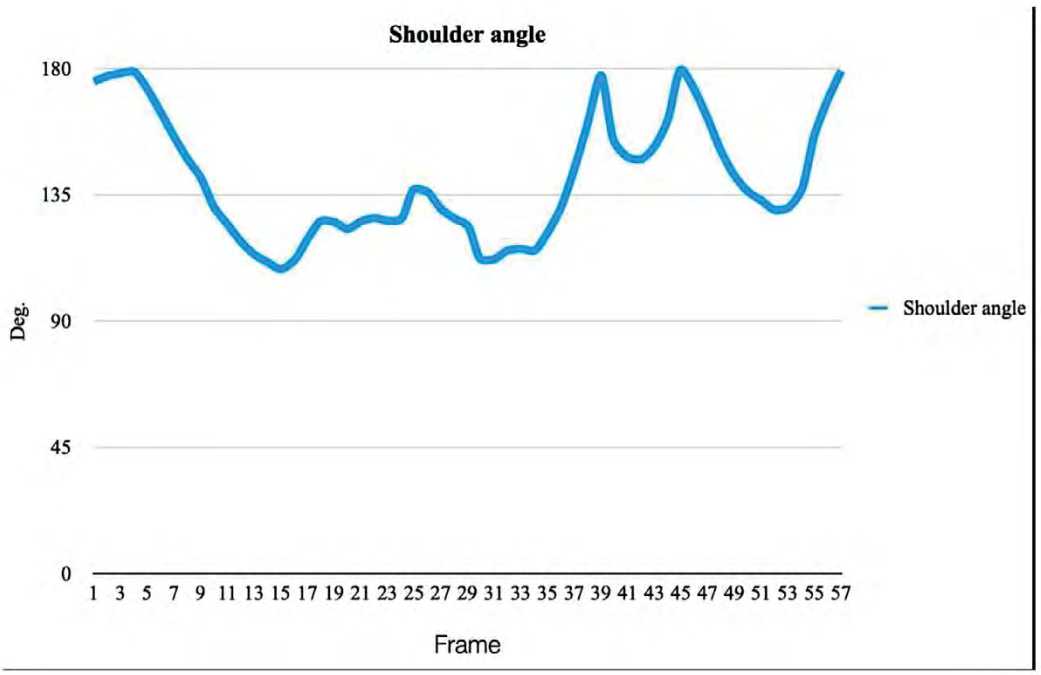

Figure 9. *Shoulder angle*

In the final phase, after reaching the highest position of the body, the gymnast directs her arms toward the high bar of the uneven bars, and the body begins to flex. At the moment of regrasping the bar, the body rounds into a hollow position and re-enters a support phase.

DISCUSSION

The kinematic analysis confirms the key factors required for the successful execution of the "Maloney" element, namely:

- The precise timing of toe-on contact with the bar (frame 24, at an angle of 28°), which enables the gymnast to build the velocity necessary for technically correct execution;
- The angular dynamics of extension in the shoulder and hip joints, which ensures an effective flight from the low to the high bar;
- The controlled transition into the correct body position and regrasp of the high bar on the uneven bars.

Limitations of the study

This study is based on a single observation of one athlete, which restricts the ability to generalize findings. However, it provides educational benefits by illustrating the technical execution of a complex element and its application in training. The analysis emphasizes how even a single performance can serve as an instructional model for coaches and athletes, highlighting the importance of precise timing, coordination, and safety in skill acquisition.

These findings not only confirm the effectiveness of the technique used by elite gymnasts but also emphasize the importance of coordinated movement between the shoulders and hips throughout the various phases of the element.

The study complements previous scientific work and analyses by Takei (1991), Hiley & Yeadon (2007), Irwin et al. (2014), and others, all of whom have highlighted the role of kinematic and biomechanical characteristics in the performance of complex elements on the uneven bars. In contrast to broader studies, this research provides a focused examination of a specific skill performed in a competitive environment, thereby increasing the practical applicability of the results.

CONCLUSION

In conclusion, it can be stated that the correct execution and coordination of the key technical components in the Maloney skill allow for the progression toward learning a more complex variation of the kinematic sequence, involving a ½ turn around the longitudinal axis during the flight phase. This study may contribute to the learning process and optimization of the technical execution of this element in practical gymnastics training. Furthermore, as the study does not include a comparative analysis, its primary contribution is educational. The findings can support the training of athletes and the optimization of sports performance for the

specific performer. Even a single kinematic analysis allows for synthesizing general conclusions about technique and its optimization in practice, underlining the applied educational value of the work.

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Corresponding author:
Emil Stoimenov, PhD
Department gymnastics
National Sports Academy "Vassil Levski"
Sofia, Bulgaria
E-mail: stoimenov@nsa.bg

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