KINEMATIC INDICATORS OF PASSE TECHNICAL MOVEMENT OF ARTISTIC GYMNASTS BY USING 3D MA TECHNOLOGY

Tursunova Dilshoda Toxirjon kizi

Teacher of Namangan State University

E-mail: tursunova dilshoda1991@gmail.com

Tel: 99 973 39 68

Abstract. This study investigates the kinematic indicators of the passé technical movement in artistic gymnasts using 3D motion analysis (MA) technology. The research focuses on analyzing key biomechanical parameters, including gait-run temporal and spatial data, joint kinematics of the lower and upper body, and coordination during the passé movement. Special attention is given to flight time, support time, braking and propulsion forces, as well as joint angles and ranges of motion. The findings reveal critical insights into movement symmetry, efficiency, and potential imbalances, which can influence performance and increase injury risk. This analysis underscores the value of 3D MA technology in optimizing the execution of complex gymnastic movements, providing actionable recommendations for improving technique and addressing biomechanical inefficiencies.

Key words: passé, artistic gymnastics, kinematic analysis, 3D motion analysis, joint kinematics, movement efficiency, symmetry, injury prevention.

КИНЕМАТИЧЕСКИЕ ПОКАЗАТЕЛИ ТЕХНИЧЕСКОГО ДВИЖЕНИЯ PASSÉ ХУДОЖЕСТВЕННЫХ ГИМНАСТОК С ИСПОЛЬЗОВАНИЕМ ТЕХНОЛОГИИ 3D MA

Турсунова Дилшода Тохиржон кизи

Преподаватель Наманганского государственного университета

E-mail: tursunova dilshoda1991@gmail.com

Тел: 99 973 39 68

Аннотация. В статье исследуются кинематические показатели passé-технического движения у художественных гимнастов с использованием технологии анализа движений 3D (MA). Исследование сосредоточено на анализе ключевых биомеханических параметров, включая временные и пространственные данные ходьбы, кинематику суставов нижней и верхней части тела, а также координацию во время движения passé. Особое внимание уделяется времени полета, времени поддержки, тормозным и движущим силам, а также углам суставов и диапазону движений. Результаты показывают важную информацию о симметрии, эффективности и потенциальном дисбалансе движений, которые могут повлиять на производительность и увеличить риск травм. Этот анализ подчеркивает ценность технологии 3D MA для оптимизации выполнения сложных гимнастических движений, предоставления практических рекомендаций по улучшению техники и устранению биомеханической неэффективности.

Key words: Passé, художественная гимнастика, кинематический анализ, 3D-анализ движения, кинематика суставов, эффективность движений, симметрия, предотвращение травм.

3D MA TEXNOLOGIYASIDAN FOYDALANGAN BADIIY GIMNASTIKACHILARNING PASSÉ TEXNIK HARAKATINI O‘TISHNI KINEMATIK KO'RSATKICHLARI

Tursunova Dilshoda Toxirjon qizi

Namangan davlat universiteti o‘qituvchisi

E-mail: tursunova dilshoda1991@gmail.com

Tel: 99 973 39 68

Annotatsiya. Ushbu maqolada badiiy gimnastika sportchilari tomonidan bajariladigan passé texnik harakatining kinematik ko'rsatkichlarini 3D harakat tahlili (MA) texnologiyasidan foydalanib o'rganiladi. Tadqiqotning asosiy maqsadi yurish-yugurish vaqti va fazoviy ma'lumotlari, yuqori va pastki tananing bo'g'im kinematikasi va passé harakati paytidagi koordinatsiyani o'z ichiga olgan asosiy biomekanik parametrlarni tahlil qilishga qaratilgan. Topilmalar harakatning simmetriyasi, samaradorligi va natijalarga ta'sir qilishi va jarohat xavfini oshirishi

mumkin bo’lgan potentsial muvozanatsizliklari haqida muhim tushunchalarni ochib beradi. Ushbu tahlil murakkab gimnastik harakatlarni bajarishni optimallashtirishda 3D MA texnologiyasining qiymatini ta'kidlaydi, texnikani yaxshilash va biomexanik samarasizlikni bartaraf etish bo'yicha amaliy tavsiyalar beradi.

Key words: passé, badiiy gimnastika, kinematik tahlil, 3D harakat tahlili, bo'g'im kinematikasi, harakat samaradorligi, simmetriya, jarohat oldini olish.

Introduction

Artistic gymnastics demands a high level of precision, strength, flexibility, and balance, with each movement requiring an intricate combination of biomechanical efficiency and control. The Passé technical movement, frequently used in gymnastics routines, involves complex coordination between the lower and upper body, placing significant demands on joint mobility, stability, and control. Understanding the kinematic indicators of this movement is crucial for optimizing performance and preventing injury.

Kinematic analysis, particularly through the use of 3D motion analysis (MA) technology, allows for a detailed examination of movement parameters such as joint angles, temporal and spatial gait-run data, and force distribution. This non-invasive method provides accurate insights into how gymnasts execute movements and how well they maintain balance and symmetry. Even minor deviations in kinematic performance can have significant effects on execution, safety, and efficiency.

Previous studies have primarily focused on broader elements of artistic gymnastics, such as leaps, jumps, and turns, leaving more detailed movements like Passé relatively underexplored. This research aims to address this gap by applying 3D MA technology to analyze the temporal and spatial characteristics of the Passé movement, alongside joint kinematics. The findings of this study are expected to contribute to a deeper understanding of movement efficiency and provide practical recommendations for improving performance and reducing the risk of injury among gymnasts.

In recent years, the application of biomechanical analysis in artistic gymnastics has become a central focus for researchers and coaches, aiming to enhance performance while minimizing injury risk. The study of kinematic indicators—particularly through advanced tools like 3D motion analysis (MA) technology—has proven invaluable in analyzing complex gymnastic movements, including jumps, leaps, and turns (Johnson, 2018). However, there is limited research on the Passé movement, despite its frequent use in routines that require a high degree of balance, coordination, and joint mobility[1].

3D MA technology enables the precise tracking of joint angles, movement velocities, and spatial parameters, providing insights that were previously difficult to measure accurately. Evans et al. (2017) demonstrated that 3D MA technology can capture even subtle movements, making it essential for analyzing artistic gymnastics techniques, where minor deviations can significantly impact performance outcomes. In particular, the ability to measure joint kinematics during dynamic movements has been highlighted as a key factor in understanding performance efficiency and identifying asymmetries in movement (Davies & Harris, 2019).

A significant area of interest in gymnastic research is the concept of biomechanical symmetry. Studies by Smith and Lee (2021) have shown that asymmetries in joint movement, force distribution, and timing can lead to reduced performance and increased injury risk. This is particularly relevant in movements like Passé, which require balanced coordination between the left and right sides of the body. Even small asymmetries in joint kinematics can lead to inefficient movement patterns, ultimately affecting the gymnast's stability and control during execution.

Further research has emphasized the importance of temporal and spatial parameters in optimizing gymnastic movements. Winter (2009) and Nigg (2001) have shown that factors such as flight time, support time, and step length play a critical role in determining movement efficiency. Vertical oscillation and propulsion distances also provide valuable insights into the gymnast's ability to transfer energy effectively throughout the movement[2]. By analyzing these parameters in the Passé movement, this study aims to extend current knowledge on how to improve performance and maintain biomechanical balance.

Despite the progress in biomechanical research on gymnastics, there remains a gap in the literature concerning the kinematic analysis of more nuanced movements like Passé. This movement, which involves coordinated lower-body control and balance, poses unique biomechanical challenges that are not addressed in studies focused on broader gymnastic skills. Therefore, this research aims to build on existing knowledge by providing an in-depth kinematic analysis of the Passé movement using 3D MA technology, contributing valuable insights into the biomechanics of this complex movement and offering recommendations for optimizing performance.

Aim of the Research: The aim of this study is to conduct an in-depth kinematic analysis of the Passé technical movement in artistic gymnasts using 3D motion analysis (MA) technology.

Tasks of the Research:

1. Measure and analyze the gait-run temporal parameters of the Passé technical movement, including cadence, flight time, support time, and step length.

2. Evaluate the spatial parameters of the Passé movement, such as center of gravity (COG) vertical oscillation, braking distance, and propulsion distance for both the left and right sides.

3. Assess the lower and upper body kinematics by examining joint-specific movements, such as hip, knee, ankle, shoulder, and elbow flexion/extension and abduction/adduction during the execution of the Passé movement.

4. Identify and compare asymmetries between the left and right sides of the body in terms of temporal, spatial, and joint kinematic indicators to determine their potential impact on performance and injury risk.

5. Provide recommendations for training adjustments based on the kinematic findings, aimed at improving movement efficiency, optimizing performance, and minimizing the risk of injury in artistic gymnasts performing the Passé.

Research Organization: This research was conducted at the Uzbek State University of Physical Education and Sports, within the high-tech laboratory equipped with advanced 3D motion analysis (MA) technology. The state-of-the-art facility allowed for precise measurement of biomechanical parameters, making it an ideal environment for studying complex athletic movements like the Passé, a key technical movement in artistic gymnastics.

The subject of this study was an elite-level artistic gymnast with considerable competitive experience, performing the Passé as the primary focus of analysis. The research aimed to capture detailed kinematic and kinetic data associated with the movement, emphasizing joint angles, force distribution, and body coordination during the execution of this challenging technical element. The controlled laboratory environment ensured high accuracy and reliability of data collection, which is critical for analyzing the intricate biomechanical processes involved in the Passé movement.

Methods: The study employed 3D motion analysis technology to evaluate the kinematic indicators of the Passé technical movement. The experiment was conducted in the high-tech sports laboratory at the Uzbek State University of Physical Education and Sports, using a high-resolution 3D motion capture system. The subject, an elite-level gymnast, performed the Passé while being recorded by a strategically placed system of infrared cameras, which captured movement from multiple angles, providing comprehensive data on the gymnast’s motion.

Reflective markers were positioned on key anatomical landmarks, including the shoulders, spine, hips, knees, ankles, and upper extremities. These markers allowed for the precise tracking of body segment coordination, joint angles, and overall posture during the Passé. The 3D motion analysis system recorded key kinematic indicators, focusing on both temporal and spatial parameters—such as flight time, support time, step length, and joint angles—as well as the overall biomechanical efficiency of the movement.

Using the captured data, a detailed analysis of the gymnast's **hip, knee, ankle, shoulder, and elbow movements** was conducted to evaluate flexion, extension, abduction, and adduction during the Passé. This comprehensive assessment provided valuable insights into how the gymnast maintains balance and transitions smoothly between different phases of the movement, identifying potential asymmetries or inefficiencies that could affect performance.

Results: Cadence refers to the frequency of steps during the movement. In this case, 179.35 steps per minute is a relatively high cadence, which indicates a quick transition between the phases of the Passé movement (support phase and flight phase) (Table-1).

High cadence is often linked to greater control and faster transition during dynamic movements. According to Winter (2009), a higher cadence is associated with improved efficiency and smoother transitions between phases of movement. However, a balance is necessary—too high a cadence can result in rushed movements, reducing control and precision. In gymnastics, maintaining high cadence while ensuring proper balance and form is crucial for optimizing performance[3]. The high cadence observed here indicates that the gymnast is proficient at maintaining rhythm and momentum. However, it is essential to maintain control and precision, especially in more complex transitions within the Passé movement.

Table-1

Gait-Run temporal parameters of Passe technical movement of artistic gymnasts

№	Parameter	Value
1	Cadence [steps per minute]	179.35 [ppm]
2	Flight time	0.40 [s]
3	Support time	0.37 [s]
4	Step length	-43.82 [mm]
5	Right flight time	0.2488 [s]
6	Left flight time	0.3666 [s]
7	Right support time	9.6320 [s]
8	Left support time	9.3791 [s]

Flight time refers to the period during which both feet are off the ground. A flight time of 0.40 seconds suggests that the gymnast is airborne for a considerable amount of time, which is important for achieving the dynamic aesthetic of the Passé[4;5].

In technical movements like the Passé, longer flight times can indicate more control in the air. Cavagna et al. (1977) found that the ability to maintain control during airborne phases is directly related to the gymnast's ability to generate the appropriate amount of vertical lift without compromising forward momentum. However, Winter (2009) emphasized that overly extended flight times could disrupt the movement's fluidity and lead to instability upon landing or transitioning to the support phase. The flight time of 0.40 seconds reflects a balance between maintaining sufficient airborne control and ensuring a smooth transition back into the support phase. This value suggests an effective performance of the Passé, though continued monitoring of flight time consistency is essential for stability.

Support time refers to the duration during which the foot remains in contact with the ground. The measured support time of 0.37 seconds shows how long the gymnast maintains ground contact before transitioning into the next phase.

Shorter support times are often associated with more dynamic movements, as seen in McClay and Manal (1999), where it was reported that elite athletes tend to spend less time in contact with the ground during high-speed technical movements. However, excessively short support times can result in instability or a loss of balance, especially in complex movements like the Passé, which require controlled transitions from support to flight. The 0.37-second support time is indicative of quick and efficient transitions, allowing the gymnast to minimize ground contact and maintain the flow of the movement. Nonetheless, it is essential to ensure that reduced support time does not lead to instability.

The negative step length (-43.82 mm) suggests that the gymnast may be experiencing a backward movement or an imbalance during the transition between steps. Ideally, step length should be positive to reflect forward progression.

Negative step length is often indicative of poor weight transfer or imbalance. According to Hof et al. (2002), improper weight transfer can lead to inefficient movement patterns and increased risk of injury. The study emphasized that positive step length correlates with more effective and balanced transitions during technical movements like the Passé.

The negative step length may indicate that the gymnast is compensating for a lack of balance or experiencing issues with weight transfer during transitions. Addressing this issue through targeted training could improve overall movement efficiency and reduce injury risk.

Right Flight Time: 0.2488 Seconds & Left Flight Time: 0.3666 Seconds. The right flight time is shorter than the left flight time, indicating asymmetry in the time spent airborne between the two sides. The gymnast spends more time airborne on the left side (0.3666 seconds) than on the right (0.2488 seconds).

Asymmetry in flight times can lead to imbalances in movement, which affect the gymnast’s overall performance. Smith and Lee (2021) highlighted that asymmetries in dynamic movements, such as varying flight times, are often linked to differences in strength, coordination, or flexibility between the left and right sides of the body. These imbalances can result in uneven weight distribution and increased risk of injury. The notable difference between the right and left flight times indicates an imbalance in the execution of the Passé. This could be due to uneven strength or flexibility between the two sides. Corrective training aimed at balancing both flight times is essential to improve symmetry and reduce injury risk.

The support times for the right and left sides are close but not identical, with the right-side spending slightly more time in contact with the ground (9.6320 seconds) than the left (9.3791 seconds). Symmetry in support time is critical for maintaining balance and control. Winter (2009) noted that even minor differences in support times could lead to inconsistencies in movement patterns. A balanced support time ensures even weight distribution, which is particularly important in technical movements like the Passé.

The small difference in support times between the right and left sides suggests that the gymnast is slightly more reliant on the right side for stability. While this imbalance is minor, addressing it could further enhance the gymnast’s overall performance and stability during execution.

The analysis of gait-run temporal parameters in the Passé technical movement highlights a number of strengths and areas for improvement. The high cadence and balanced flight time suggest that the gymnast has mastered key aspects of the movement. However, the negative step length and asymmetry in flight and support times indicate that further work is needed to correct imbalances, particularly in the weight transfer between the left and right sides.

The vertical oscillation of the Center of Gravity (COG) during the Passé movement measures 93.87 mm, indicating significant upward and downward displacement of the gymnast’s COG (Table-2). According to Winter (2009), maintaining minimal vertical oscillation of the COG is crucial for optimizing energy efficiency in movements that require precision and balance. Excessive vertical displacement can result in higher energy expenditure and may reduce movement efficiency. The high vertical oscillation in this instance suggests that the gymnast is expending considerable energy in managing vertical movement. This might indicate an area where the gymnast could improve balance and efficiency by reducing unnecessary vertical motion.

Table-2

Gait-Run Spatial Parameters of Passe technical movement of artistic gymnasts

№	Parameter	Value
1	COG vertical oscillation	93.87 [mm]
2	Right braking distance	-34.50 [mm]
3	Left braking distance	3.36 [mm]
4	Right propulsion distance	37.26 [mm]
5	Left propulsion distance	-4.62 [mm]
6	Support distance for right contacts	209.03 [mm]
7	Support distance for left contacts	205.68 [mm]
8	X coordinate of the right toe during contacts	133.53 [mm]
9	X coordinate of the left toe during contacts	142.44 [mm]

The negative right braking distance (-34.50 mm) indicates that the right leg is encountering significant deceleration forces during the transition from flight to support phase. On the other hand, the left leg shows minimal braking force (3.36 mm), indicating an asymmetry. Novacheck (1998) pointed out that excessive braking forces can impair forward momentum and reduce movement fluidity. A balanced braking force between the left and right legs is crucial for achieving seamless transitions between phases. The large discrepancy between the right and left braking distances highlights an imbalance that could be affecting the gymnast's overall performance. The right leg is responsible for most of the deceleration, which could be contributing to asymmetry in force distribution and affecting the fluidity of the movement.

The right leg's propulsion distance (37.26 mm) indicates effective forward propulsion, while the left leg shows a negative propulsion distance (-4.62 mm), suggesting that it is not contributing effectively to forward movement.

Research by Cavagna et al. (1977) emphasizes the importance of both legs contributing equally to propulsion for optimal movement efficiency. The asymmetry seen here, with the left leg contributing negatively, indicates inefficiency in the forward motion.

This marked imbalance between the right and left propulsion distances suggests that the gymnast relies heavily on the right leg to generate forward momentum, while the left leg may be hindering movement. Corrective training focused on equalizing propulsion forces could improve movement balance and efficiency.

The support distance for the right leg (209.03 mm) is slightly greater than that for the left leg (205.68 mm), indicating a minor difference in the distance covered during ground contact between the two legs.

Symmetry in support distances is crucial for maintaining balance and stability in gymnastic movements. Hof et al. (2002) noted that uneven support distances can lead to imbalances in weight distribution, potentially affecting performance and increasing injury risk. The small difference in support distances suggests a slight asymmetry in ground contact between the legs. Although the discrepancy is minimal, addressing it could improve the gymnast's balance and overall stability during the Passé.

The X coordinate of the left toe during contact (142.44 mm) is slightly greater than that of the right toe (133.53 mm), indicating a wider stance or lateral movement on the left side during ground contact. Proper foot placement during ground contact is critical for maintaining balance and reducing unnecessary lateral motion[6]. Nordin and Frankel (2012) suggest that lateral discrepancies in toe placement can lead to uneven force distribution and potentially compromise the stability of dynamic movements.

The wider stance on the left side, as indicated by the X coordinate of the left toe, suggests an asymmetry that could affect balance and force distribution during the Passé. Correcting this lateral imbalance could enhance movement stability and reduce the risk of injury.

Conclusion

The kinematic analysis of the Passé technical movement in artistic gymnasts using 3D motion analysis technology has provided critical insights into both the strengths and areas for improvement in the movement. The analysis revealed several key findings, including asymmetries in both temporal and spatial parameters, which could impact the gymnast's performance, efficiency, and injury risk.

1. High Cadence: The gymnast demonstrated a high cadence, which reflects quick transitions and dynamic movement. However, maintaining control and balance during rapid transitions is essential to avoid overcompensating, which can compromise precision.

2. Flight and Support Times: While the overall flight and support times are indicative of a well-executed movement, the observed asymmetry between the left and right sides-particularly in-flight times-suggests an imbalance in strength or coordination between the two sides of the body. Corrective training should focus on equalizing these times to ensure symmetry and reduce the risk of injury.

3. Step Length: The negative step length highlights issues with weight transfer during the transition between phases of the movement. This could indicate a backward movement or imbalance that may lead to inefficiencies in the execution of the Passé. Targeted exercises focusing on improving weight transfer and balance during transitions could resolve this inefficiency.

4. Center of Gravity (COG) Oscillation: The vertical oscillation of the COG was relatively high, which suggests that the gymnast is expending unnecessary energy managing vertical displacement. Reducing vertical oscillation through proper balance training can lead to improved energy efficiency, better control, and reduced fatigue during performance.

5. Braking and Propulsion Forces: The significant discrepancy between the right and left braking and propulsion distances is a critical finding. The gymnast relies heavily on the right leg for propulsion and deceleration, while the left leg contributes minimally, or even negatively, to forward motion. This imbalance can affect movement fluidity and stability. Strengthening the left leg and focusing on balanced propulsion and braking forces will be essential to achieving a more symmetrical and efficient movement.

6. Foot Placement and Support Distance: The difference in the X coordinates of the right and left toes during ground contact, as well as the minor

asymmetry in support distances, suggests a slight imbalance in lateral movement and ground contact. Proper foot placement is crucial for maintaining balance and distributing forces evenly across both legs. Correcting the lateral discrepancy will improve balance and reduce the risk of instability during dynamic movements like the Passé.

REFERENCES

1. Davies, M., & Harris, G., 2019. Biomechanical insights into artistic gymnastics performance using 3D motion analysis. Journal of Sports Science, 27(4), pp.345-361.

2. Evans, T., Roberts, L., & McCloy, T., 2017. The application of 3D motion capture technology in sports biomechanics research. Sports Biomechanics, 16(2), pp.110-128.

3. Johnson, A., 2018. The biomechanical foundations of artistic gymnastics techniques. International Journal of Gymnastics Research, 5(1), pp.12-27.

4. Nigg, B.M., 2001. *The role of impact forces and foot pronation: A new paradigm. Clinical Biomechanics, 16(1), pp.19-24.

5. Smith, P., & Lee, J., 2021. Lower body kinematic asymmetry and its impact on performance in artistic gymnastics. Journal of Biomechanics, 55(3), pp.89

6. Winter, D.A., 2009. *Biomechanics and motor control of human movement. 4th ed. Hoboken: John Wiley & Sons.