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Video-Based Performance Analysis of West Java Artistic Swimming

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Abstract

The purpose of this study was to analyze the performance of artistic swimmers from West Java using video as a more objective evaluation tool. Athlete performance has usually been assessed directly, which can lead to subjectivity. Kinematic analysis was used for data from three female athletes from qualifying round of the 2025 West Java Provincial Sports Week and the 2025 West Java Regional Sports Championship . Leg height index (LHI) and average leg angle deviation (LAD) in vertical and knight movements were calculated using Kinovea software for frame-by-frame data extraction. The LAD was calculated based on the angle deviation from the ideal position, and the LHI values were compared to the FINA standard height card. The analysis results show that there are quite noticeable technical differences between the subjects. SSK a showed the best and most consistent performance, with an average LHI of 9.5 (Vertical) and 9.6 (Knight) that was closer to the FINA standard, and her LAD was also relatively small on both elements. AEN demonstrated a stable LHI (9.1 Vertical; 9.2 Knight). Compared to other athletes, AEN LAD values tended to be higher, which may indicate that she reached sufficient height to make utilizing the angles around her peak more difficult. Meanwhile, LNL achieved a lower LHI (9.1 Vertical; 8.9 Knight) as well as the smallest LAD value in the Knight movement (1.3°). Although her vertical LAD (5.9°) was higher than AEN. The results indicate that video-based performance analysis can be successfully applied to the evaluation of artistic swimming performance.

How to Cite

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INTRODUCTION

Swimming, gymnastics, ballet, and dance are interwoven into a single artistic and technical performance in artistic swimming, a water sport. To compete, athletes are required to possess excellent physical abilities, perfect technical skills, and a keen sense of rhythm and music (Danardani et al., 2018). Performance assessment is a crucial part of the training process because, at the competitive level, the precision of an athlete›s movements and the ability to consistently repeat technical elements influence artistic swimming score points. Coaches still often rely on direct visual inspection, which, according to field experience, has difficulty accurately capturing technical details, movement dynamics, and synchronization (Yue et al., 2023).

Recent advances in video-based recognition have significantly improved the accuracy and objectivity of evaluating athlete performance in sports (Yin et al., 2024). Video-based performance analysis has become an essential approach in technical and aesthetic sports to evaluate movement execution and identify performance characteristics through systematic visual observation. Previous research has suggested that video review grounded in visual information, allows the participant to improve movement execution processes as a result of more exposures to performance (Woll & Wagner, 2022). In relation to artistic swimming, the importance of video analysis is even greater due to the specific features of this sport, where both above and below the water action are based on synchronization and details (Quinlan et al., 2015). Nonetheless, the study looking at artistic swimming performance with video in particular for athletes from certain areas including West Java is still very rare.

This gap in research emphasizes the need to consider utilizing video-based performance analysis to contribute towards technical assessment practice in artistic swimming. Video-based approaches to performance evaluation in relation to swimming have been demonstrated to be valid and reliable (Matúš et al., 2025). It is therefore necessary to establish a research methodology that not only measures athlete's performance, but also provides data an coach could use for the decision-making in designing training programs. However, analysis of specific technical elements, such as Leg Height Index and Leg Angel Deviation in artistic swimming, is still limited.

This study aims to address this need by analyzing the performance of West Java artistic swimmers using a video-based approach. Through frame-by-frame analysis and identification of movement patterns, this study aims to provide an objective evaluation of athletes' technical performance, in line with recent developments in video-based motion analysis (Xiao et al., 2023). In addition, previous studies in swimming have shown that visual-based performance analysis provides practical information that can support coaches in monitoring and evaluating performance (Szczepan et al., 2016).

The problem formulation of this study focuses on how video analysis can be used to objectively identify and evaluate the quality of athlete movement in artistic swimming. Specifically, this study aims to: (1) analyze the movement quality of West Java artistic swimming athletes using video-based performance analysis, with particular emphasis on movement synchronization between athletes; and (2) generate technical recommendations based on quantitative movement indicators to support performance improvement. The novelty of this study lies in the application of systematic video-based analysis to evaluate synchronization quality in artistic swimming within a regional competitive context, providing objective performance indicators that have rarely been reported in previous studies.

METHOD

This study uses a quantitative descriptive approach and a video-based performance analysis design. This design allows for objective technical measurements by examining the height and angle of the legs during the Knight and Vertical movements. Because it offers excellent accuracy in recognizing movement characteristics, the video technique is frequently employed in biomechanical investigations, especially kinematic analysis. (Yue et al., 2023). Quantitative research applies a systematic and scientific approach to collect and analyze numerical data for describing phenomena objectively (Siroj et al., 2024). The data was analyzed using Microsoft Excel.

This study uses a quantitative descriptive research design based on video analysis (video-based motion analysis).

This design was chosen to objectively describe the technical performance of artistic swimmers through quantitative measurements in the form of Leg Height Index (LHI) and Leg Angle Deviation (LAD) in the Vertical and Knight elements. The analysis did not cover the entire rou-

tine, but focused on these two elements because they are the main technical components listed in the FINA Height Cards reference.

The population of this study consisted of athletes participating in the qualifying round of the 2025 West Java Provincial Sports Week and the 2025 West Java Regional Sports Championship events in the solo free routine category for age group B. The sampling technique used was purposive sampling, with a total of three female athletes participating.

Purposive sampling is a non-probability sampling technique in which researchers consciously select participants based on specific criteria deemed most relevant to answering the research objectives. In this method, researchers do not select samples randomly, but select individuals who are considered to fully display the Vertical and Knight elements in the match video, so that they can provide accurate technical information for LHI and LAD calculations and have the knowledge, experience, or specific characteristics to provide in-depth and meaningful information (Tajik et al., 2024).

The research instrument used to measure the performance of Artistic Swimming figures (Vertical and Knight elements) is based on the Single-Plane Kinematic Analysis System. The equipment used includes:

1. Recording Equipment: an iPhone 13 camera is used as the main recorder. The camera was operated at a minimum frame rate of 60 frames per second (fps) to ensure the quality of movement required for kinematic analysis.
2. Analysis Software: Kinovea motion analysis software version 0.9.5 was used for joint point digitization, spatial calibration, and video processing (Escalona-marfil et al., 2019).
3. Standard References: The Artistic Swimming Handbook, the FINA Artistic Swimming Scoring Handbook, and the FINA Height Card are used to compare Leg Height Index (LHI) scores and Leg Angle Deviation (LAD) angles (World Aquatics, 2021).

To ensure measurement validity, criterion validity and content validity were employed. Criterion validity was achieved by combining Kinovea with a high-frame-rate camera (60 frames per second), perpendicular motion field recording to minimize parallax error, and spatial calibration to ensure measurement precision. This approach is in line with studies (Escalona-marfil et al., 2019) that demonstrated Kinovea's validity in measuring distances and angles with high reliability (ICC > 0.95). The choice of LHI and LAD parameters, which are important technical elements in FINA rules and assessment criteria, supports content validity (World Aquatic, 2023). Reliability was ensured through the application of a single rater protocol, in which the same rater repeated digitization on the peak frames of LHI and LAD. Recent studies (Elgendy et al., 2024) also showed very high reliability (ICC > 0.99) in Kinovea-based measurements.

The motion analysis process in this work was based on the approach (Yue et al., 2023), which employed Kinovea software to assess motion synchronization using the LHI and LAD parameters. The athletes' performance under competitive settings is represented by the data acquired from video recordings made during the competition on October 19–21, 2025. An iPhone 13 camera with a minimum frame rate of 60 frames per second was used to record, and it was positioned steadily perpendicular to the athlete's path. Kinovea was then used to analyze the videos, beginning with the selection of the steady point on the Knight and the peak frame of the vertical position. The Leg Angel Deviation (LAD) and the Leg Height Index (LHI) were the two primary metrics that were measured.

A quantitative descriptive method was used to analyze the data. Kinovea was used to extract video frames, measure the Leg Height Index (LHI) and Leg Angle Deviation (LAD), and compute the average value of each movement element. The angle difference from the ideal position was used to examine the LAD, while the LHI value was compared to the FINA Height Cards norm. The results of each athlete were then compared to illustrate.

RESULTS AND DISCUSSION

This chapter presents and explains the results of the research that has been conducted. An initial analysis was performed to identify the average LHI values of athletes in both elements. LHI values were compared with FINA Height Cards standards (ideal value = 10). The average LHI measurement results can be seen in **Table 1.**

Based on **Table 1**, there is a clear difference in the Leg Height Index (LHI) values between athletes in the vertical and knight elements. SSK showed the best performance with an LHI value of 9.5 in the vertical and 9.6 in the knight, which was the highest value among all athletes. This value is also the closest to the FINA Height Cards standard (LHI = 10), indicating that SSK foot position is at an almost ideal height when performing both vertical and knight elements. It

Table 1. Average Leg Height Index (LHI)

Athlete Name	Category	Movement	LHI	FINA Standard	FINA Deviation	Description
SSK	Solo Free Routine	Vertical	9.5	10	-0.5	Indicates a leg height value slightly below the FINA standard
		Knight	9.6	10	-0.4	Indicates a leg height value very close to the FINA standard
AEN		Vertical	9.1	10	-0.9	Indicates a leg height value moderately below the FINA standard
		Knight	9.2	10	-0.8	Indicates a leg height value moderately below the FINA standard
LNL		Vertical	9.1	10	-0.9	Indicates a leg height value moderately below the FINA standard
		Knight	8.9	10	-1.1	Indicates a leg height value below the FINA standard

Table 2. Average Leg Angle Deviation (LAD)

Athlete Name	Category	Movement	LAD (°)	Deductions	Description
SSK	Solo Free Routine	Vertical	4.7	0.2	Indicates a moderate leg angle deviation.
		Knight	4.5	0.2	Indicates a moderate leg angle deviation.
AEN		Vertical	13.6	0.2	Indicates a large leg angle deviation.
		Knight	8.0	0.2	Indicates a moderate to large leg angle deviation.
LNL		Vertical	5.9	0.2	Indicates a moderate leg angle deviation.
		Knight	1.3	0.2	Indicates a small leg angle deviation.

can be inferred that SSK has steady and reliable leg elevation control because the greater the LHI value, the closer it is to the ideal standard.

With an LHI rating of 9.1 in the vertical and 9.2 in the knight, AEN, on the other hand, performed rather steadily. This score is still within the good performance category and demonstrates AEN ability to maintain a somewhat constant leg height, even though her position is little lower than SSK. However, the deviation from the standard (around -0.9 in the vertical and -0.8 in the knight) indicates that AEN leg height has not yet fully reached the FINA optimal level, although it still shows adequate control.

On the other hand, LAL received the lowest LHI scores, namely 9.1 for the vertical and 8.9 for the knight, making her the athlete with the lowest leg elevation from the FINA standard. The knight LHI score of 8.9 was the lowest among the three athletes, with a deviation of -1.1 from the ideal standard. A smaller LHI indicates that the foot height is lower and elevation control is not as optimal as other athletes, so the body position tends to be less stable and more prone to a decrease in height during execution.

Overall, **Table 1** shows that the knight element tends to produce slightly higher LHI values than the vertical for all athletes, indicating that the knight position is biomechanically easier to maintain than the vertical, especially in maintaining leg elevation. This pattern is consistent across all three athletes, although variations in performance between athletes remain evident.

Table 2 An essential metric for assessing artistic swimming technique is the Mean Leg Angle Deviation (LAD) value. For the Vertical element, where the ideal position is completely perpendicular, LAD calculates the degree to which the leg angle deviates from the ideal stable position. As a result, a low LAD value (around 0 degrees) denotes better performance, which reflects ideal body control and the athlete's capacity to keep a perfect "line" on the water's surface a critical technical evaluation criterion. On the other hand, a high LAD value is a symptom of subpar performance, suggesting considerable instability that could be brought on by ineffective sculling technique (arm raising action), poor core muscular control, or trouble staying balanced, all of which would lower the artistic value (Homma et al., 2023).

Through the Deductions system, this angle deviation directly affects the technical score: a slope of 0° to 15° results in a deduction of -0.2 points, a slope of 15° to 30° results in a deduction of -0.5 points, and a slope of more than 30° results in a deduction of -1.0 points (World Aquatics, 2021).

The Leg Angle Deviation (LAD) metric was used to assess the athletes' body angle sta-

bility; lower values suggest better body control and stability. Significant differences exist between people and between elements in the actual LAD data that is displayed. LAL achieved the highest absolute stability performance on the Knight element with a LAD value of under 1.3 degrees. This accomplishment demonstrates outstanding alignment and body control in the Knight posture. LAL deviance, however, was somewhat greater in the Vertical element, coming in at 5.9 degrees. As a result, each athlete's average deduction for the total performance under analysis was -0.2 points.

On both components, SSK shown outstanding and reliable stability. On the Vertical, her LAD value was 4.7 degrees; on the Knight, it was marginally better at 4.5 degrees. SSK appears to have a great core strength and control, as seen by this consistency, which allows her to adjust to the technical demands of both elements without suffering a significant increase in deviation. AEN, on the other hand, has the most severe stability issues. With a LAD score of 13.6 degrees, she had the largest deviance on the Vertical element. This graphic highlights how difficult it is for the athlete to keep a straight body line and balance.

Although her deviation decreased on the Knight element to 8.0 degrees, this value is still the highest among all subjects on the Knight element. In contrast, the Knight factor helped most athletes (LAL and SSK) achieve greater stability (lower LAD). However, AEN greatest variation on the Vertical (13.6 degrees) and the comparison of Vertical and Knight as a whole show that Vertical is typically a more difficult element for athletes in terms of body angle stability.

The results of the study showed that the performance of three West Javanese artistic swimming athletes in the Vertical and Knight elements had significant variations in body stability (LAD) and leg height (LHI). This finding is in line with (Yue et al., 2023), which states that elements with inverted positions such as Vertical require high body control, so that slight variations in body angle can affect the execution assessmen. Furthermore, differences in LHI values among athletes in this study illustrate differences in their ability to consistently maintain leg height according to FINA Height Card standards. SSK demonstrated the closest performance to the standard, with the highest average LHI comparable to 9.5 in Vertical and 9.6 in Knight. Conversely, the highest LHI rating in LAL, equal to 8.9 in Knight, was the lowest; this indicates a lack of sculling or propulsion power.

The LAD parameter also shows the existence of body angle deviations which is essential to stability. (Liu et al., 2025) a large angular deviation signifies poor core control and body orientation that affect the general skill ability of the element. This variation could be well quantified by kinematic analysis: LAL achieved the highest stability in the Knight (LAD=1.3°), AEN incurred the greatest deviation doing so in the Vertical element (13.6°). This quantifiable difference supports that athletes have different challenges, with 13/6° offset requiring an intense core strenghthening programme.

This study confirms the findings of (Edriss et al., 2024), hat video analysis can detect, accurately identify, and quantify technical errors that may not be visible to coaches in real time and should be addressed by judges. In other words, in competition, video analysis tends to allow for more objective performance evaluation. This information aligns with performance patterns that can be used to modify training redesigns, including delivering LADs closer to zero, which is crucial for minimizing the risk of FINA-compliant deductions.

Overall, the results of this study indicate that the LHI and LAD-based video analysis approach is highly relevant for evaluating the individual performance of artistic swimming athletes. These findings also emphasize the need for improvements in body stability, core control, and leg height consistency to enhance technique quality in accordance with FINA international standards. Therefore, video-based performance analysis can be an effective evaluation tool for coaches in designing more measurable and specific training programs.

CONCLUSION

This study concludes that the video-based performance analysis is an effective method for evaluating the quality of artistic swimmers' movements, particularly in the vertical and knight elements. The LHI and LAD parameters offer an objective insight into the leg height, body stability and angle deviation which impact on the quality of technique realization.

These findings of the study indicate there are differences in body control and movement consistency that were not develop fully after they had completed all elements for competition routines. The method of video analysis enables coaches to look for errors at a particular event which, in return, can make the training more efficient. Therefore, this study provides a performance assessment model that can be utilized for training

and the evaluation process in competition as it aids artistic swimming training.

On the field, video data analysis provides a less subjective evaluation approach for performance under competition. Performance characteristics, as shown through this technical information, suggest training needs to be optimized with the goal of keeping LAD as close to 0 as possible; preferably at 0 in an attempt to minimize potential deductions as per FINA rules.

In general, the performances suggested that the LHI and LAD-based video analysis method seems to be highly applicable in assessing individual artistic swimmers. These findings also confirm the need for improvement in body stability, core control, and leg height consistency in order to improve technical quality in accordance with FINA international standards. Thus, video-based performance analysis can be an effective evaluation tool for coaches in designing more measurable and specific training programs.

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