Journal of Coaching and Sports Science
Volume 4, Issue 2, 118-130.
e_ISSN: 2963-1483
https://www.journal.foundae.com/index.php/jcss/index
DOI: 10.58524/jcss.v4i2.890

Integration of Biomechanics and Digital Technology: Using Kinovea for Motion Analysis and Learning for Beginner Athletes

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Article Info

Article history:
Received: August 9, 2025
Revised: September 15, 2025
Accepted: November 24, 2025

Keywords:
Athletic performance;
Biomechanics;
Kinovea;
Motion analysis;
Sport technology.

Abstract

Background: The integration of biomechanics with digital motion-analysis technologies has introduced new approaches for examining movement efficiency, kinematic characteristics, and technical patterns in walking and running activities. Kinovea, as an accessible motion-analysis software, provides both visual and quantitative feedback. However, its application in supporting technique development among beginner athletes remains insufficiently explored.
Aim: This study aims to describe the use of Kinovea in biomechanics training and examine its contribution to the awareness of kinematic characteristics and movement techniques among beginner athletes.
Methods: A descriptive qualitative design involved 72 beginner athletes aged 18–25 years selected through purposive sampling. Data were collected over 16 weeks through interviews, field observations, and motion video recordings analyzed using Kinovea. Kinematic data focused on joint angles, stride behavior, and movement phases during walking, running, and the flight phase. Qualitative data were analyzed using content analysis with NVivo 12, while kinematic results were interpreted descriptively to identify performance patterns and areas for technical refinement.
Result: Kinematic analysis showed coordinated joint-angle patterns across all phases. Walking analysis identified arm swing angles of 50.9°–58.8° and leg separation angles of 64.3°–67.2°, indicating a stable gait rhythm. The running analysis revealed knee angles of 68.8°–69.8° and elbow angles of 87.6°–89.1°, indicating efficient propulsive mechanics. The flight phase demonstrated knee angles of 81.2°–87.8° and elbow angles of 80.4°–88.3°, suggesting effective momentum use and postural stability. These measurements supported stride-efficiency assessment and technique evaluation. Qualitative findings revealed that Kinovea enabled athletes to interpret movement phases and identify technical inefficiencies through slow-motion and frame-by-frame visualization.
Conclusion: Kinovea supports basic motion analysis by providing clear kinematic information and helping beginner athletes observe and refine their movement techniques. The findings also offer practical value for coaches by enabling more precise identification of inefficient patterns and guiding targeted corrections during early-stage training.

To cite this article: Hudha, M. N., Probosari, R. M., Khasanah, A. N., Supurwoko., Nisa', S. K., & Latief, G. R. G. (2025). Integration of biomechanics and digital technology: Using kinovea for motion analysis and learning for beginner athletes. *Journal of Coaching and Sports Science, 4*(2), 118-130. https://doi.org/10.58524/jcss.v4i2.890

INTRODUCTION

Biomechanics has become an essential component of modern sports performance analysis, as it provides a scientific explanation for how athletes generate force, move efficiently, and reduce the likelihood of injury during physical activity (Giustino & Patti, 2025; Mahmood et al., 2025). When biomechanical information is measured accurately, coaches can assess the quality of an athlete's technique more objectively and design training programs grounded in evidence rather than intuition

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(Knudson, 2017; Potop et al., 2024). In running, for instance, biomechanical evaluation offers insight into how the joints coordinate, how propulsion forces are produced, and how different body segments interact to support athletic performance (Wallace & Kernozek, 2017).

Research on walking and running mechanics consistently shows that coordination between the spine, pelvis, and lower limbs plays a major role in shaping an individual's gait development and movement fluency (Kiely & Collins, 2016; Preece et al., 2016). Coordination across the limbs is also a determining factor in sprint acceleration, particularly during the initial phases when large propulsive forces are generated (Donaldson et al., 2022; Haugen et al., 2019). One key element of running is the flight or hovering phase, when both feet leave the ground. The flight or hovering phase, when both feet leave the ground, reflects an explosive capability that significantly contributes to stride effectiveness (Lim et al., 2020; Pezaro et al., 2024). Understanding the characteristics of each phase allows coaches and beginner athletes to detect technical issues earlier and improve performance more systematically.

Despite the importance of biomechanical information, beginner athletes commonly struggle to identify technical errors during training. Many movement patterns, such as joint alignment, swing coordination, phase transitions, and force orientation, are difficult to perceive accurately without external feedback (Keogh et al., 2024; Knudson, 2022; Wallace & Kernozek, 2017). Reliance on internal perception alone often leads to misunderstandings between what athletes believe they are doing and what they actually perform. This gap highlights the need for visual tools that can present movement mechanics more concretely.

Advances in digital technology have helped address this challenge, primarily through motion-analysis tools. Similar trends are reported in educational technology research, which highlights how digital tools enhance observation, analytical thinking, and self-regulated learning (Listiyana et al., 2023). These tools enable detailed movement visualization, automatic computation of kinematic variables, and visual feedback that is easier for beginner athletes to interpret. Through video reviews, athletes can observe their movement patterns, compare phases, and recognize technical inefficiencies that require correction. The effectiveness of digital media in facilitating conceptual understanding has also been highlighted in research, where interactive e-modules improved students' analytical and critical thinking skills (Wahyudi et al., 2025). This reinforces the potential of motion analysis technologies, such as Kinovea, to help athletes interpret complex biomechanical patterns. Such technology strengthens movement awareness and supports more effective skill acquisition during early training stages.

Kinovea is one of the most accessible tools used for motion analysis. As an open-source platform, it can measure joint angles, stride length, movement speed, and phase duration using simple video recordings (Balsalobre-Fernández et al., 2014; García et al., 2024; Adnan et al., 2018). Studies have confirmed the validity and reliability of Kinovea, particularly its strong correspondence with three-dimensional motion capture systems when measuring gait parameters (Fernández-González et al., 2020). Additional research has explored its application in numerous sport contexts, such as high jump technique evaluation (Adnan et al., 2018; Pueo et al., 2020), countermovement jump assessment (Caseiro-Filho et al., 2023; Emamian et al., 2024), scapular motion examination (Elrahim et al., 2016; Sneha M et al., 2025), and joint position accuracy analysis (Puig-Diví et al., 2019; Yazdani et al., 2022). Its low cost, ease of use, and slow-motion and frame-by-frame features make it highly suitable for sport coaching and applied biomechanics.

However, systematic evaluations of how biomechanics and digital technology intersect using Kinovea, particularly among beginner athletes, remain limited. Through precise movement visualization and clearer kinematic feedback, coaches are better able to detect technical errors at an early stage of training and provide more targeted interventions. Such analysis helps beginner athletes develop movement patterns that are more effective and efficient from the outset. Therefore, this study examines the use of Kinovea as a motion analysis tool within a biomechanical context and evaluates its contribution to movement quality, kinematic awareness, and technique interpretation among beginner athletes.

METHOD

Research Design

This study employed a descriptive qualitative design to explore the experiences of beginner athletes participating in biomechanics training that incorporated motion analysis using Kinovea. This design was chosen because it enables an in-depth understanding of how participants perceive movement assessment during walking, running, and the flight phase, all of which are closely related to the development of athletic technique (Byrd, 2020; Kim et al., 2017). A descriptive approach also allows the documentation of contextual details and reflective insights throughout the training process.

Participant

This study involved 72 novice athletes aged 18 to 25 who had no prior experience with motion-analysis software. The participants were categorized as novice athletes, defined as individuals with less than six months of structured training experience and no history of competition in their respective sports. They were selected based on their willingness to complete the full 16-week program and were considered suitable for examining the development of biomechanical analysis skills. All participants provided informed consent before participating in the study, and ethical considerations were ensured through the use of anonymity, voluntary participation, and institutional ethical approval.

Population and Sampling

The study involved 72 beginner athletes aged 18 to 25 years who met the criteria of novice athletes, defined as individuals with less than six months of structured training experience and no prior participation in competitive events in their respective sports. Participants were selected using purposive sampling based on their suitability for biomechanics-based instruction and their willingness to complete the full 16-week program. Ethical considerations were ensured through informed consent, voluntary participation, confidentiality of participant identity, and approval from the institutional ethics committee. The sampling strategy adhered to the principle of information power (Malterud et al., 2016), ensuring that the number of participants was sufficient to produce rich and meaningful qualitative data.

Instrument

The primary instrument for biomechanical assessment was the Kinovea software version 0.9.5, which enabled analysis of joint angles, stride patterns, ground-contact characteristics, movement speed, and the flight phase. A digital camera operating at 60 frames per second (fps) with a 1920 × 1080 resolution was used to record all movement sequences. Additional instruments included semi-structured interview guides, weekly reflective journals, and classroom observation sheets, which collectively captured participants' learning experiences and responses to motion-analysis activities. These instruments were used consistently throughout the 16-week training program.

Data Analysis

Data were analyzed qualitatively using a qualitative content analysis approach (Vaismoradi & Snelgrove, 2019), which allowed themes to emerge inductively from participants' narratives. The analysis involved repeated reading of interview transcripts, reflective journals, and observation notes to identify statements. Systematic coding was conducted using NVivo 12 to categorize data related to participants' experiences with Kinovea as a biomechanics and performance-analysis tool. Kinematic data generated through Kinovea were analyzed descriptively to illustrate joint-angle patterns, key movement phases, and biomechanical indicators during walking, running, and the flight phase. These measurements were integrated into the qualitative interpretation to clarify movement contexts and provide concrete examples of performance characteristics relevant to coaching and technique evaluation. Credibility was supported through triangulation of data sources (interviews, observations, video analysis).

RESULTS AND DISCUSSION

Results

The kinematic analysis revealed consistent and well-coordinated movement patterns across the walking, running, and flight phases performed by beginner athletes. Synchronization between arm swing and lower-limb movement demonstrated a stable step rhythm and efficient load distribution throughout the locomotion cycle. These patterns align with Newton's Second Law, which states that changes in velocity and acceleration reflect the magnitude of propulsive forces generated through joint flexion and extension. During the running phases, especially in propulsion, the mechanics also correspond with Newton's Third Law, where the backward force applied by the foot generates a forward ground-reaction force that accelerates the athlete. Meanwhile, consistent leg elevation during the flight phase suggests optimal use of momentum produced in the preceding step. Collectively, the findings highlight the integration of force production, acceleration control, and intersegmental coordination indicative of efficient locomotor performance.

Biomechanical Analysis of Walking Movement

Walking movement represents a fundamental human locomotion pattern that biomechanically involves coordination of joint angles, stride length, movement velocity, force generation, and body stability (Fandaklı et al., 2018). Efficient gait performance relies on the synchronized interaction between upper- and lower-limb segments, facilitating smooth weight transfer, minimizing mechanical stress, and promoting energy-efficient movement patterns. The present analysis examines three key walking positions: initial contact, mid-stance, and terminal stance, to highlight performance-related indicators such as stride efficiency, joint coordination, and lower-limb load distribution.

Figure 1. First Walking Position

The analysis of the walking phase shows a progressive and interconnected development of mechanical patterns across the initial contact, mid-stance, and terminal stance phases. In the first position show in Figure 1, the arm swing angle was recorded at 54.6°, while the leg separation angle measured 67.2°, indicating stable and reciprocal coordination between the arms and legs that serves as the foundation for step initiation. The relatively wide leg separation observed at this stage supports early momentum and facilitates an efficient transfer of load to the supporting limb. This mechanism also helps reduce excessive stress on the knee joint during initial contact, thereby lowering the risk of injuries associated with repetitive loading.

Figure 2. Second Walking Position

Moving to the second position show in Figure 2, the mid-stance phase shows an increase in the arm swing angle to 58.8°, while the leg angle narrows to 65.3°. This shift reflects effective balance control as the body passes over the supporting limb. The coordinated motion of the upper extremities plays a crucial role in maintaining dynamic stability and step rhythm, thereby contributing to a smoother transfer of body weight. Efficient mechanics during mid-stance also help minimize excessive lateral movement, which is essential for preventing ankle instability during walking.

Figure 3. Third Walking Position

The third position, shown in Figure 3, displays an arm swing angle of 50.9° and a leg separation angle of 64.3°, indicating the attainment of an optimal stride length just before the forward push-off. This configuration reflects the readiness of the limbs to generate efficient propulsion, with proper alignment of the extremities playing a crucial role in ensuring an effective transfer of force into the subsequent step. Maintaining stability during terminal stance also helps minimize unnecessary impact on the lower limb joints. Overall, the mechanics observed in the walking sequence demonstrate efficient stride length, consistent joint coordination, and balanced load distribution. These elements represent key indicators of locomotion efficiency and serve as protective factors against the risk of lower-limb injury.

Biomechanical Analysis of Running Movement

The running movements performed by the participants displayed kinematic patterns that require coordinated joint action, controlled propulsive force, and regulated stride length to maintain speed. The variations in knee and elbow angles observed across phases illustrate how athletes utilize the interaction between ground reaction forces and body momentum to achieve steady acceleration (Dobre & Gheorghe, 2021; Hamner et al., 2020). Based on these considerations, the analysis is divided into three primary phases: the propulsive phase, the flight phase, and the preparation for ground contact phase.

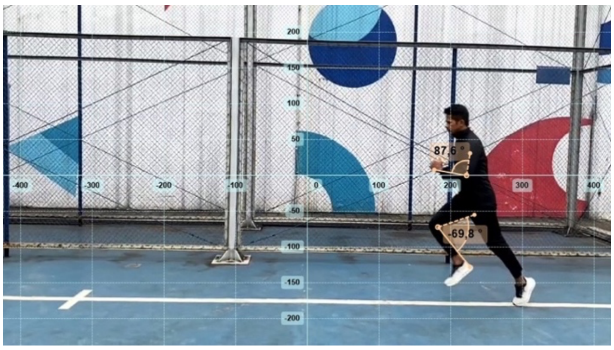

Figure 4. First Running Position

The propulsive phase is shown in Figure 4. The rear knee angle was recorded at 69.8°, and the elbow angle reached 87.6°, indicating the athlete's ability to generate substantial propulsive force as the foot makes contact with the ground. This mechanical action aligns with Newton's Third Law of Action and Reaction, where a greater downward and backward force from the foot results in a stronger ground reaction force that propels the body forward. The nearly vertical elbow angle contributes to the rotational stability of the trunk. It enhances the efficiency of the arm swing, both of which play key roles in maintaining rhythm and sustaining acceleration during sprinting.

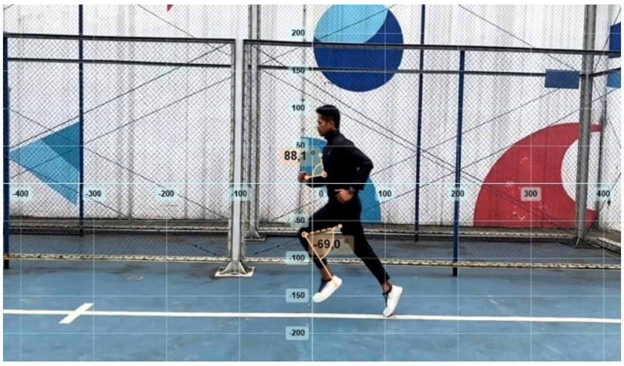

Figure 5. Second Running Position

The transition into the flight phase, as shown in Figure 5, exhibits a front-knee angle of 69.0° and an elbow angle of 88.1°, representing the moment when both feet are completely off the ground. This phase relies entirely on the propulsive momentum generated in the preceding phase. Higher knee lift and stable arm swing contribute to increased stride length, which directly enhances sprint speed. Efficient mechanics during the flight phase also help reduce braking forces when the foot recontacts the ground, thereby lowering the risk of ankle and knee injuries.

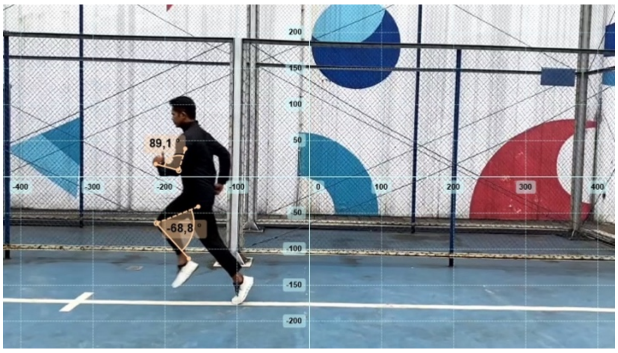

Figure 6. Third Running Position

During the preparation-for-ground-contact phase show in Figure 6, the front knee angle of 68.8° and the elbow angle of 89.1° indicate optimal readiness for impact absorption and joint stiffness control just before the foot meets the ground. Proper positioning of the extremities at this stage allows for efficient force distribution, reduces excessive joint loading, and prepares the body for the next step in the gait cycle. The coordination between the knee movement and arm swing helps maintain body stability and ensures continuity of speed as the athlete transitions into the subsequent stride. Overall, the analysis of the running motion highlights the efficiency of propulsive force, speed development, stride-length optimization, and synchronized arm–leg movement. These four components represent essential indicators of improved sprint performance as well as protective factors that help reduce injury risk resulting from inefficient movement patterns.

Biomechanical Analysis of Hovering Phase During Running

The variations in knee and elbow angles observed during the flight phase illustrate how athletes maintain horizontal momentum and regulate stride length throughout a sprint. The precision of limb positioning at this stage determines the effectiveness of force transfer from the preceding propulsive phase and influences stability as the body prepares for the next ground contact (Donaldson et al., 2022; Lim et al., 2020). Based on these considerations, three key positions were analyzed to assess the consistency of knee lift, the rhythm of arm swing, and the body's readiness before re-establishing ground contact.

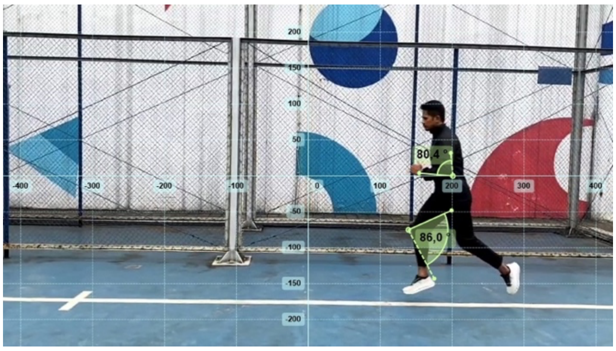

Figure 7. First Hovering Position

The first hovering position, shown in Figure 7, has a front-knee angle of 86.0°, while the elbow angle is recorded at 80.4°. This configuration reflects an optimal level of knee elevation before the limb enters the peak-swing stage. The high knee lift indicates a significant contribution from explosive power generated during the preceding propulsive phase, enabling the body to move forward with sufficient momentum. At the same time, the stable elbow angle helps maintain rotational balance and supports a consistent movement rhythm while the body is entirely in the hovering phase.

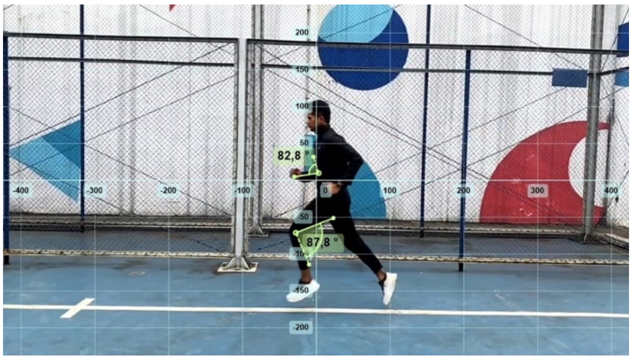

Figure 8. Peak Hovering Position

The next position, shown in Figure 8, indicates that the front knee angle increases slightly to 87.8°, while the elbow angle is recorded at 82.8°. This moment represents the peak of the hovering phase, in which both feet are entirely off the ground. The position reflects the achievement of maximum stride length before the transition into the preparation-for-ground-contact phase. The stability of the limbs at the peak of the hovering phase helps minimize braking forces when the foot returns to the ground, thereby contributing to the maintenance of sprinting speed and overall stride-cycle efficiency.

Figure 9. Terminal Hovering Position

In the final hovering phase on Figure 9, the front-knee angle reaches 88.3°, and the elbow angle measures 81.2°, indicating that the limb is fully prepared to enter ground contact with optimal joint stiffness control. This configuration reflects proper alignment between the knee, hip, and arm swing, which helps minimize impact forces when the foot strikes the ground while maintaining speed continuity into the next propulsive phase. Postural stability during this stage is crucial for preserving sprint rhythm and minimizing the risk of injury associated with inefficient landing patterns.

Considered as a whole, the hovering-phase analysis illustrates an effective integration of explosive power, arm-swing rhythm, and stride-length regulation in sustaining maximal sprint velocity. Precise limb positioning while the body is airborne not only enhances mechanical efficiency but also serves as a protective mechanism, reducing braking forces and lowering the risk of injury. Stability and consistency in knee lift throughout the hovering sequence serve as indicators of an athlete's readiness to maintain high-speed running performance across subsequent stride cycles.

In addition to these kinematic findings, interview data provide further insight into how participants interpreted the motion-analysis process using Kinovea. Through conventional content analysis, it became clear that Kinovea offered a meaningful learning experience for beginner athletes in understanding and evaluating biomechanical movement. Athletes' beginners reported that visualizing their movements through slow-motion playback and joint-angle measurements made it easier to understand phases of motion that previously felt abstract in theory. Many noted that they only began to truly grasp when the knee should be lifted, how arm swing contributes to acceleration, and how stride patterns shift across different phases of walking and running after reviewing their own recordings. This was reflected in the statement of one participant.

Respondent 1 *:"When it was only explained in theory, I could not visualize what the knee angle should look like while running. After seeing it through Kinovea, I immediately understood when the knee needs to rise and how the arm swing contributes to acceleration."*

Improving their understanding of biomechanics, participants also demonstrated growth in technical analysis skills and performance awareness. By using angle-measurement tools and reference lines, they were able to identify technical weaknesses in both themselves and their training partners, such as movement asymmetry, insufficient propulsive force, inefficient arm-swing patterns, and suboptimal posture during ground contact. This development is reflected in the following statements:

Respondent 2 *: "I initially thought my technique was already correct, but the analysis showed that my left-leg push-off was still weak. That made me focus more on improving that part during training."*

Respondent 3 *: "Watching my own movement felt like looking in a mirror, but with far more detail. I could see the angles clearly and understand what needed to be fixed."*

These findings suggest that Kinovea serves not only as a tool for visualizing biomechanical patterns but also as a reflective medium that enhances kinesthetic awareness, helping participants adjust their techniques independently. The integration of motion-analysis technology supports more applied learning and contributes to athletic performance improvement through clear, accessible feedback.

Discussion

The findings of this study indicate that the use of Kinovea as a biomechanical analysis tool provides clearer insight into segmental relationships, step mechanics, and how participants regulate movement coordination during walking and running. The visualizations produced through slow-motion and frame-by-frame features enabled athletes to identify coordination patterns that would have been difficult to observe through conventional visual inspection. This is consistent with Pueo et al. (2020), who showed that video-based feedback enhances perceptual accuracy and facilitates earlier recognition of technical errors. In the context of gait, the athletes demonstrated rhythmic step patterns and consistent interaction between the upper and lower limbs, supporting the observations of Fandaklı et al. (2018) Fernández-González et al. (2020). This finding is also supported, showing that Kinovea can detect subtle variations in gait patterns with strong reliability. The walking sequences recorded in this study, therefore, align with the foundational biomechanical standards described in the literature.

The consistency observed in participants' walking patterns further illustrates the effective transfer of load and segmental alignment of the torso, hips, and legs. This interaction is essential for maintaining energy efficiency, reducing mechanical stress, and lowering injury risk. Previous gait research by Gupta et al. (2023). It highlights that stable postural alignment serves as a significant indicator of efficient movement control, a pattern evident in the participants' gait cycles. Analysis of the running phases revealed well-coordinated transitions across the propulsive, hovering, and pre–ground contact phases. These mechanical patterns align with findings by Hamner et al. (2020), which suggest that propulsive forces in sprinting are primarily generated through the interplay between muscular output and ground mechanics. Likewise, Dobre & Gheorghe (2021) noted that effective sprinting depends heavily on smooth phase transitions and the ability to sustain momentum, both of which were reflected in the participants' running sequences.

The alignment of this study's findings with those of Donaldson et al. (2022) further supports the crucial role of upper–lower limb coordination in improving stride length and sustaining velocity. The recorded arm-swing and knee-drive patterns demonstrate acceleration mechanisms that reflect established sprint-biomechanics frameworks. The limb-elevation patterns observed during the hovering phase also parallel the description by Lim et al. (2020), who noted that knee lift plays a central role in regulating stride behavior and maintaining forward momentum during running. Beyond the observable joint patterns, beginner athletes in this study showed substantial growth in their understanding of movement biomechanics after reviewing their recorded motion. Many reported being able to distinguish between perceived movement and actual movement only after visualizing their own footage. This aligns with Prasetya et al. (2025), who found that visual feedback increases self-awareness and improves accuracy in identifying technical deviations among novice athletes. Through this process, beginner athletes were able to recognize biomechanical inefficiencies they previously believed to be correct.

The clarity of the biomechanical patterns revealed through Kinovea also has long-term relevance for athlete development. Early identification of technical inefficiencies such as asymmetrical limb motion, insufficient propulsive force, or unstable hovering mechanics enables coaches to provide more precise and targeted training adjustments. Correcting these issues at the beginner stage is essential because inefficient movement patterns that persist into later stages of athletic development become increasingly difficult to change and may restrict long-term performance potential. Through systematic biomechanical feedback at an early level, beginner athletes can develop more effective and efficient movement habits that support their progression toward higher performance levels and reduce future injury risks, forming a stronger foundation for eventual elite-level training.

Video-based analysis also facilitated the recognition of technical deviations that may not be easily detected through observation alone. These include asymmetry between limbs, insufficient propulsive force, and inconsistent arm-swing amplitude, which are commonly identified in early-stage athletes. Findings by Adnan et al. (2018) and Sneha et al. (2025) similarly highlight the ability of video analysis to reveal subtle deviations that influence mechanical efficiency. The present study supports these conclusions, showing that beginner athletes were able to identify technical details with greater precision after reviewing their recorded motion. From a learning perspective, the use of Kinovea provided athletes with a more concrete understanding of biomechanical concepts by enabling them to observe their own performance directly. This aligns with Pueo et al. (2020), who reported that visualization enhances comprehension of movement phases and supports the internalization of biomechanical knowledge. The combination of kinematic measurement and self-observation played a crucial role in enabling athletes to distinguish between efficient and inefficient movement patterns.

Overall, the results demonstrate that beginner athletes were able to internalize biomechanical concepts more effectively through visual motion analysis and that the movement patterns they displayed reflect biomechanical characteristics consistent with previous research. These findings also show that early exposure to detailed movement visualization can contribute to the development of coordinated and efficient motion patterns, laying a foundation that may support advanced performance development should the athletes progress toward higher competitive levels.

Implications

The findings of this study demonstrate that integrating Kinovea into biomechanics training offers practical value for coaches and novice athletes by providing objective visual and kinematic information that helps identify technical inefficiencies, such as asymmetrical steps, weak propulsive phases, and postural deviations. This clarity enables coaches to design more precise and targeted early-stage interventions, allowing beginner athletes to develop efficient and coordinated movement patterns before progressing to higher levels of performance. At the same time, the visualization features support athletes' self-awareness and independent technique evaluation, reinforcing the development of foundational biomechanical understanding. Furthermore, the ability to detect technical inefficiencies at an early stage has long-term relevance for athlete development. Early correction of coordination errors, insufficient propulsion mechanics, or unstable flight patterns may prevent these inefficient habits from carrying over into higher levels of training. This contributes to a stronger biomechanical foundation, which can support more advanced performance demands should beginner athletes later progress toward elite competition.

Research Contribution

This study provides three key contributions. First, it integrates kinematic analysis with qualitative insights from novice athletes, offering a comprehensive understanding of how motion-analysis technology supports the learning and interpretation of biomechanical concepts. Second, the findings reinforce existing evidence on the reliability of Kinovea as a low-cost and accessible tool for performance analysis in coaching and educational settings. Third, the study contributes a new perspective by demonstrating that video-based motion analysis not only improves the accuracy of technical evaluation but also enhances kinesthetic awareness, motivation to train, and active engagement in learning among beginner athletes.

Limitations

Several limitations should be acknowledged when interpreting these findings. The kinematic analysis examined only selected key positions and did not capture the whole dynamics of locomotion, such as stride-to-stride variability, temporal parameters, or rhythm fluctuations across movement phases. The participant group, consisting exclusively of novice athletes aged 18–25 years, also restricts the generalizability of results, particularly to trained or elite athletes who experience higher biomechanical demands. Furthermore, the qualitative approach provided detailed insight into athletes' learning experiences but did not quantify performance improvements or biomechanical adaptations over time.

Suggestions

Considering these limitations, future research may incorporate additional biomechanical instruments, such as inertial motion sensors, force plates, or 3D motion-capture systems, to generate more comprehensive datasets that combine kinematic and kinetic variables. Including athletes from varying sport disciplines or performance levels would also broaden the understanding of Kinovea's utility across different training contexts. For coaching practice, the present findings may serve as a foundation for using Kinovea as a practical monitoring tool to help coaches evaluate technique, detect early signs of injury risk, and provide ongoing, targeted corrections throughout training cycles.

CONCLUSION

This study demonstrates that integrating Kinovea into biomechanics provides beginner athletes with clearer representations of walking and running movement patterns through precise visualizations and standardized kinematic descriptions. The joint-angle and locomotion-phase analyses offered athletes a more concrete basis for understanding how their movements are structured and where technical inefficiencies may occur. Kinovea also supported athletes in observing their own movement characteristics, interpreting coordination patterns, and engaging in reflective evaluation of their techniques. As an accessible motion-analysis tool, Kinovea served not only as an analytical instrument but also as a medium that helps athletes form a more meaningful understanding of biomechanical principles and movement execution within early-stage sport training contexts.

ACKNOWLEDGMENT

The authors extend their sincere gratitude to the novice athletes who participated in this study and to the lecturers who provided support throughout the data collection process. Their cooperation and commitment contributed greatly to the completion of this research. This activity is funded by non-state budget funds of Universitas Sebelas Maret (non APBN UNS) under contract number: 371/UN27.22/PT.01.03/2025.

AUTHOR CONTRIBUTION STATEMENT

MNH, RMP, S, SKN, and GR jointly designed the study and developed the methodological framework. MNH led the data collection and kinematic analysis. ANK conducted the qualitative analysis and organized the thematic interpretation. MNH and SKN prepared the manuscript draft and coordinated revisions based on peer feedback. All authors reviewed the final version of the manuscript and approved its submission.

AI DISCLOSURE STATEMENT

The author used Kinovea during the preparation of this work for movement analysis (biomechanics). After using the tool/service, the author thoroughly reviewed and edited the content as needed and takes full responsibility for the content of the publication. The authors declare that this research was prepared, researched, written, and edited without the aid of artificial intelligence (AI) techniques.

CONFLICTS OF INTEREST

The authors confirm the presence or absence of any potential conflicts of interest—financial, institutional, or personal—that could influence the conduct of this study, the analysis of data, the preparation of the manuscript, or its publication.

REFERENCES

Adnan, N. M., Ab Patar, M. N. A., Lee, H., Yamamoto, S.-I., Jong-Young, L., & Mahmud, J. (2018). Biomechanical analysis using Kinovea for sports application. *IOP Conference Series: Materials Science and Engineering*, *342*, 012097. https://doi.org/10.1088/1757-899X/342/1/012097

Balsalobre-Fernández, C., Tejero-González, C. M., del Campo-Vecino, J., & Bavaresco, N. (2014). The concurrent validity and reliability of a low-cost, high-speed camera-based method for measuring the flight time of vertical jumps. *The Journal of Strength & Conditioning Research*, *28*(2), 528–533. https://doi.org/10.1519/JSC.0b013e318299a52e

Byrd, R. (2020). Qualitative research methods. *Virtual Class, Memphis. Recuperado Em*, *17*. Sage Publishing.

Caseiro-Filho, L. C., Girasol, C. E., Rinaldi, M. L., Lemos, T. W., & Guirro, R. R. J. (2023). Analysis of the accuracy and reliability of vertical jump evaluation using a low-cost acquisition system. *BMC Sports Science, Medicine and Rehabilitation*, *15*(1), 107. https://doi.org/10.1186/s13102-023-00718-z

Dobre, A. G., & Gheorghe, C. (2021). The optimization of the running technique using video analysis method. *Journal of Physics: Conference Series*, *1746*(1), 012086. https://doi.org/10.1088/1742-6596/1746/1/012086

Donaldson, B. J., Bezodis, N. E., & Bayne, H. (2022). Inter-and intra-limb coordination during initial sprint acceleration. *Biology Open*, *11*(10), 1-11. https://doi.org/10.1242/bio.059501

Elrahim, R. M. A., Embaby, E. A., Ali, M. F., & Kamel, R. M. (2016). Inter-rater and intra-rater reliability of Kinovea software for measurement of shoulder range of motion. *Bulletin of Faculty of Physical Therapy*, *21*(2), 80–87. https://doi.org/10.4103/1110-6611.196778

Emamian, A., Oskouei, A. H., Kipp, K., & Azreh, R. (2024). Performance of artificial neural network compared to multi-linear regression in prediction of countermovement jump height. *Journal of Bodywork and Movement Therapies*, *40*(1), 2211–2217. https://doi.org/10.1016/j.jbmt.2024.11.001

Fandaklı, S. A., Okumuş, H. İ., & Öztürk, M. (2018). A study of human walking biomechanics for ankle-foot prosthesis design. *2018 6th International Conference on Control Engineering & Information Technology (CEIT)*, 1–5. https://doi.org/10.1109/CEIT.2018.8751801

Fernández-González, P., Koutsou, A., Cuesta-Gómez, A., Carratalá-Tejada, M., Miangolarra-Page, J. C., & Molina-Rueda, F. (2020). Reliability of kinovea® software and agreement with a three-dimensional motion system for gait analysis in healthy subjects. *Sensors*, *20*(11), 3154. https://doi.org/10.3390/s20113154

García, T. C. G., Parada, M. F. B., & Leiva, K. M. R. (2024). Biomechanical analysis of functional movement in athletes using kinovea. In H.-N. Costin, R. Magjarević, & G. G. Petroiu. (eds) *Advances in Digital Health and Medical Bioengineering.* EHB 2023. IFMBE Proceedings, vol 111. Springer, Cham. ttps://doi.org/10.1007/978-3-031-62523-7_52

Giustino, V., & Patti, A. (2025). Biomechanics and sports performances. *Sports, 13*(1), 73. https://doi.org/10.3390/sports13030073

Gupta, A., Shrestha, P. L., Thapa, B., Silwal, R., & Shrestha, R. (2023). Knee flexion/extension angle measurement for gait analysis using machine learning solution "MediaPipe Pose" and its comparison with Kinovea®. *IOP Conference Series: Materials Science and Engineering*, *1279*(1), 012004. https://doi.org/10.1088/1757-899X/1279/1/012004

Hamner, S. R., Seth, A., & Delp, S. L. (2020). Muscle contributions to propulsion and support during running. *Journal of Biomechanics*, *43*(14), 2709–2716. https://doi.org/10.1016/j.jbiomech.2010.06.025

Haugen, T., McGhie, D., & Ettema, G. (2019). Sprint running: From fundamental mechanics to practice—a review. *European Journal of Applied Physiology*, *119*(6), 1273–1287. https://doi.org/10.1007/s00421-019-04139-0

Keogh, J. W. L., Moro, C., & Knudson, D. (2024). Promoting learning of biomechanical concepts with game-based activities. *Sports Biomechanics*, *23*(3), 253–261. https://doi.org/10.1080/14763141.2020.1845470

Kiely, J., & Collins, D. J. (2016). Uniqueness of human running coordination: The integration of modern and ancient evolutionary innovations. *Frontiers in Psychology*, *7*, 262. https://doi.org/10.3389/fpsyg.2016.00262

Kim, H., Sefcik, J. S., & Bradway, C. (2017). Characteristics of qualitative descriptive studies: A systematic review. *Research in Nursing & Health*, *40*(1), 23–42. https://doi.org/10.1002/nur.21768

Knudson, D. (2017). Qualitative biomechanical principles for application in coaching. *Sports Biomechanics*, *6*(1), 109–118. https://doi.org/10.1080/14763140601062567

Knudson, D. (2022). Do low-tech active-learning exercises influence biomechanics student's epistemology of learning? *Sports Biomechanics*, *21*(7), 773–781. https://doi.org/10.1080/14763141.2019.1682650

Lim, J., Hamill, J., Busa, M. A., & van Emmerik, R. E. (2020). Changes in coordination and variability during running as a function of head stability demands. *Human Movement Science*, *73*(1), 102673. https://doi.org/10.1016/j.humov.2020.102673

Listiyana, A., Bima, M. Z. A., Khusna, N., Dewi, P. W. C., Putri, S. R., Yuniarti, Y., … Sukardi, R. R. (2023). Implementation of STEM-oriented learning strategy toward science literacy skills in elementary school students. *Journal of Environment and Sustainability Education, 1*(1), 20–26.

Mahmood, M. Z., Khaskheli, N. A., & Noreen, Z. (2025). The role of biomechanics in enhancing athletic performance. *Al-Aijaz Research Journal of Islamic Studies & Humanities*, *9*(1), 331–340. https://doi.org/10.55544/jrasb.1.5.26

Malterud, K., Siersma, V. D., & Guassora, A. D. (2016). Sample size in qualitative interview studies: guided by information power. *Qualitative Health Research*, *26*(13), 1753–1760. https://doi.org/10.1177/1049732315617444

Pezaro, S., Zarbiv, G., Jones, J., Feika, M. L., Fitzgerald, L., Lukhele, S., Mcmillan-Bohler, J., Baloyi, O. B., da Silva, K. M., & Grant, C. (2024). Characteristics of strong midwifery leaders and enablers of strong midwifery leadership: An international appreciative inquiry. *Midwifery*, *132*(1), 103982. https://doi.org/10.1016/j.midw.2024.103982

Potop, V., Mihailescu, L. E., Mihaila, I., Zawadka-Kunikowska, M., Jagiello, W., Chernozub, A., Baican, M.-S., Timnea, O. C., Ene-Voiculescu, C., & Ascinte, A. (2024). Applied biomechanics within the Kinesiology discipline in higher education. *Physical Education of Students*, *28*(2), 106–119. https://doi.org/10.15561/20755279.2024.0208

Prasetya, F., Fortuna, A., Samala, A. D., Latifa, D. K., Andriani, W., Gusti, U. A., Raihan, M., Criollo-C, S., Kaya, D., & García, J. L. C. (2025). Harnessing artificial intelligence to revolutionize vocational education: Emerging trends, challenges, and contributions to SDGs 2030. *Social Sciences & Humanities Open*, *11*(1), 101401. https://doi.org/10.1016/j.ssaho.2025.101401

Preece, S. J., Mason, D., & Bramah, C. (2016). The coordinated movement of the spine and pelvis during running. *Human Movement Science*, *45*(1), 110–118. https://doi.org/10.1016/j.humov.2015.11.014

Pueo, B., Penichet-Tomas, A., & Jimenez-Olmedo, J. M. (2020). Validity, reliability and usefulness of smartphone and kinovea motion analysis software for direct measurement of vertical jump height. *Physiology & Behavior*, *227*(1), 113144. https://doi.org/10.1016/j.physbeh.2020.113144

Puig-Diví, A., Escalona-Marfil, C., Padullés-Riu, J. M., Busquets, A., Padullés-Chando, X., & Marcos-Ruiz, D. (2019). Validity and reliability of the Kinovea program in obtaining angles and distances using coordinates in 4 perspectives. *PloS One*, *14*(6), e0216448. https://doi.org/10.1371/journal.pone.0216448

Sneha, M., Ramana, M., & Matharasi, A. P. (2025). A quasi-experimental investigation of scapular stabilization exercises on muscle coordination and functional recovery in scapular dyskinesia. *Journal of Orthopaedic Reports*, *4*(10), 100609. https://doi.org/10.1016/j.jorep.2025.100609

Vaismoradi, M., & Snelgrove, S. (2019). Theme in qualitative content analysis and thematic analysis. *Forum: Qualitative Social Research*, *20*(3), 23. https://doi.org/10.17169/fqs-20.3.3376

Wahyudi, A. B. E., Salimi, M., Hidayah, R., Surya, A., Suhartono, S., & Wahyono, W. (2025). Local wisdom-based science e-module to improve cultural literacy and critical thinking skills of elementary school students. *Journal of Environment and Sustainability Education, 3*(3), 387–395.

Wallace, B., & Kernozek, T. (2017). Self-efficacy theory applied to undergraduate biomechanics instruction. *Journal of Hospitality, Leisure, Sport & Tourism Education*, *20*(1), 10–15. https://doi.org/10.1016/j.jhlste.2016.11.001

Yazdani, S., Eftekhari, H., & Khaffafpour Komeili, M. (2022). Validity and reliability of Kinovea software in evaluation of shoulder joint position sense in female volleyball players. *Journal of Advanced Sport Technology*, *6*(2), 146–155. https://doi.org/ 10.22098/jast.2022.2210