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Relationship Between Kinematic Analysis Of Sprint Running Movement And Athletic Learning Strategies In Schools: A Systematic Review

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A. Conception and design of the study; **B.** Acquisition of data;
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ABSTRACT

Sprint running is one of the fundamental skills in athletics learning that requires proper movement mechanics to achieve optimal performance and effective learning outcomes. However, athletics instruction in schools often emphasizes performance results rather than the quality of movement execution, resulting in limited utilization of biomechanical evidence in teaching practices. Therefore, this study aimed to systematically examine the relationship between sprint running kinematic analysis and athletics learning strategies in school settings from both conceptual and empirical perspectives. This study employed a Systematic Literature Review (SLR) following the PRISMA 2020 guidelines. Literature was collected from Scopus, Web of Science, ScienceDirect, PubMed, ERIC, Google Scholar, SINTA, and Garuda databases covering publications from 2015–2025. A total of 186 articles were identified, of which 24 studies met the inclusion criteria and were included in the final synthesis. Data were analyzed using a thematic synthesis approach focusing on sprint kinematic variables and instructional strategies in physical education. The results revealed that stride length (75.0%), stride frequency (70.8%), and joint-angle mechanics (62.5%) were the most frequently investigated kinematic variables. Furthermore, 79.2% of the reviewed studies reported significant improvements in sprint technique and learning outcomes when biomechanical feedback, video analysis, motion-capture systems, or technology-assisted learning strategies were implemented. The findings indicate that sprint kinematic analysis enhances movement awareness, technical proficiency, and instructional effectiveness. In conclusion, sprint kinematic analysis serves not only as a performance assessment tool but also as an evidence-based pedagogical resource that can improve athletics learning quality in schools through the integration of biomechanics, motor learning principles, and technology-supported instruction.

Keywords : Sprint Kinematics, Athletics Learning, Biomechanics, Physical Education, Systematic Review.

INTRODUCTION

Athletics is one of the fundamental components of physical education that plays a strategic role in developing students' physical literacy, motor competence, and lifelong participation in physical activity. Among various athletic events, sprint running is considered a basic locomotor skill that requires the integration of neuromuscular coordination, biomechanical efficiency, and technical mastery. Sprint performance is determined not only by physiological capacities such as muscle power and speed but also by the quality of movement execution reflected through kinematic variables, including stride length, stride frequency, joint angles, trunk inclination, ground contact time, and limb coordination (Valamatos et al., 2022). Research in sports biomechanics has demonstrated that kinematic efficiency significantly contributes to sprint acceleration and maximal velocity performance.

In educational settings, sprint learning is often implemented through traditional demonstration-practice approaches without comprehensive biomechanical analysis. Consequently, many students execute sprint techniques with improper body posture, inefficient arm swing, excessive braking forces, and suboptimal stride mechanics. These technical deficiencies reduce running efficiency and limit the achievement of learning outcomes in athletics. Recent studies indicate that sprint technique should be analyzed systematically using biomechanical principles to identify movement errors and provide evidence-based feedback during instruction (Rumini et al., 2024). Furthermore, the implementation of athletics learning in schools frequently emphasizes performance outcomes rather than movement quality. Teachers often evaluate sprint achievement solely based on running time, while neglecting the kinematic factors underlying sprint performance. This condition creates a pedagogical gap because students may achieve moderate performance levels while still exhibiting inefficient movement patterns that could hinder long-term skill development. From a motor learning perspective, effective learning strategies should integrate biomechanical feedback to facilitate the acquisition of optimal movement patterns and enhance students' understanding of sprint mechanics.

The increasing availability of video analysis applications, markerless motion capture systems, and digital learning technologies provides new opportunities for integrating kinematic analysis into athletics education. Markerless biomechanical systems have shown promising results in evaluating sprint mechanics with acceptable accuracy for educational and coaching contexts, enabling teachers to provide objective feedback on students' movement execution. Therefore, understanding the relationship between sprint kinematic analysis and athletics learning strategies becomes essential for improving instructional quality in schools. Theoretical foundations of sprint biomechanics are primarily derived from the biomechanical principles of human locomotion, which explain that sprint performance is influenced by the interaction between kinematic, kinetic, and neuromuscular variables. Kinematic analysis focuses on the description of movement patterns without considering the forces causing motion. Important sprint kinematic indicators include stride length, stride frequency, hip extension angle, knee flexion angle, ankle stiffness, trunk lean, and arm swing coordination (Pietraszewski et al., 2025).

Recent systematic reviews have identified that elite sprinters consistently demonstrate greater horizontal force application, shorter ground contact times, optimal trunk positioning, and more effective stride characteristics compared with lower-level performers (Valamatos et al., 2022). Similarly, Rumini et al. (2024) reported that biomechanical variables such as stride frequency, stride length, and body posture are critical determinants of sprint performance and should be integrated into athlete development and technical instruction. From an educational perspective, motor learning theories suggest that movement acquisition becomes more effective when learners receive augmented feedback regarding movement execution. Schmidt's Schema Theory and Newell's Constraints Theory emphasize that movement refinement occurs through continuous interaction between task demands, environmental conditions, and individual characteristics. Consequently, integrating biomechanical analysis into athletics instruction may enhance students' movement awareness and facilitate skill acquisition.

Empirical studies have also demonstrated the effectiveness of sprint-specific interventions in improving movement mechanics. Resisted sprint training, plyometric training, combined strength-sprint programs, and phase-specific sprint drills have been shown to improve acceleration, stride mechanics, and sprint performance by modifying kinematic characteristics. These findings suggest that movement quality and learning strategies are closely interconnected.

In physical education, contemporary pedagogical approaches such as Teaching Games for Understanding (TGfU), Sport Education Model (SEM), and technology-assisted learning increasingly emphasize movement analysis and reflective learning. Video-based feedback, motion analysis applications, and digital coaching tools allow students to observe, evaluate, and improve their sprint techniques systematically. Such approaches align with constructivist learning theory, which encourages learners to actively construct knowledge through observation, reflection, and problem-solving.

Moreover, advances in sports science have promoted the use of biomechanical assessment as an instructional tool rather than merely a performance evaluation method. Studies examining running biomechanics have shown that movement variables significantly influence efficiency and performance outcomes, supporting the integration of biomechanical concepts into educational practice. Although numerous studies have investigated sprint biomechanics, acceleration performance, sprint training methods, and athletic development, most research has focused on competitive athletes, elite sports performance, and training interventions. Limited attention has been given to how sprint kinematic analysis can be utilized as a pedagogical foundation for athletics learning in school environments.

Previous systematic reviews primarily examined biomechanical determinants of sprint performance, muscle activation patterns, resisted sprint training, and acceleration mechanics. However, these studies rarely explored the educational implications of kinematic findings or their relationship with learning strategies employed by physical education teachers. Additionally, existing literature often treats biomechanics and pedagogy as separate domains. Biomechanics studies generally focus on performance optimization, whereas educational research emphasizes instructional models without integrating biomechanical evidence. Consequently, there remains insufficient understanding regarding how kinematic indicators can inform the design, implementation, and evaluation of athletics learning strategies in schools.

Another significant gap concerns the lack of synthesis connecting sprint kinematic variables with contemporary instructional approaches such as video-assisted learning, biomechanical feedback, digital learning technologies, and evidence-based physical education. While technological tools are increasingly available, systematic evidence regarding their pedagogical effectiveness remains fragmented. Therefore, a systematic review is needed to bridge the gap between sprint biomechanics and athletics education by synthesizing current evidence on how kinematic analysis contributes to instructional effectiveness, movement skill acquisition, and sprint learning outcomes among students.

The objective of this systematic review is to analyze and synthesize scientific evidence regarding the relationship between sprint running kinematic analysis and athletics learning strategies in school settings. Specifically, this study aims to identify the key kinematic variables associated with sprint performance, examine their educational implications, and evaluate how biomechanical findings can support the development of effective athletics learning strategies. The novelty of this review lies in its interdisciplinary integration of sports biomechanics and physical education pedagogy. Unlike previous reviews that focused solely on performance enhancement or sprint training interventions, this study positions sprint kinematic analysis as a pedagogical framework for athletics instruction. The review also highlights the potential role of technology-assisted biomechanical assessment in supporting evidence-based teaching practices, improving movement quality, and enhancing students' motor learning experiences.

In conclusion, sprint running is a fundamental athletic skill whose effectiveness is strongly influenced by kinematic movement characteristics. While substantial evidence exists regarding the biomechanical determinants of sprint performance, limited attention has been devoted to their application within school-based athletics learning. The separation between biomechanics and pedagogy has created a research gap that restricts the development of evidence-based instructional strategies. Therefore, this systematic review seeks to provide a comprehensive synthesis of current literature on the relationship between sprint kinematic analysis and athletics learning strategies, offering theoretical and practical contributions to the advancement of physical education and athletics instruction in schools.

METHODS

This study employed a Systematic Literature Review (SLR) design to comprehensively examine the relationship between sprint running kinematic analysis and athletics learning strategies in school settings. The systematic review approach was selected because it enables researchers to synthesize empirical findings from diverse studies, identify research trends, evaluate methodological quality, and generate evidence-based conclusions regarding a particular phenomenon (Page et al., 2021). In the context of sports science and physical education, systematic reviews have become an important method for integrating biomechanical and pedagogical evidence to support decision-making in instructional practice.

The review protocol followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure transparency, reproducibility, and methodological rigor. The literature search was conducted across several reputable scientific databases, including Scopus, Web of Science, ScienceDirect, PubMed, ERIC, Google Scholar, SINTA, and Garuda. The search process covered publications from 2015 to 2025, considering that the last decade has witnessed substantial advancements in sprint biomechanics, motion analysis technology, and pedagogical innovation in physical education. Keywords and Boolean operators were combined as follows: "sprint kinematics" OR "running biomechanics" OR "sprint technique" AND "athletics learning" OR "physical education" OR "teaching strategy" OR "school athletics". Similar search strategies have been employed in recent systematic reviews investigating sprint biomechanics and performance determinants.

The inclusion criteria comprised: (1) peer-reviewed journal articles published in English or Indonesian; (2) studies examining sprint kinematic variables such as stride length, stride frequency, joint angles, trunk inclination, or ground contact time; (3) studies discussing athletics instruction, motor learning, or physical education contexts; and (4) empirical, review, or experimental studies with accessible full texts. Meanwhile, studies focusing exclusively on physiological adaptations without biomechanical variables, conference abstracts, theses, editorials, and duplicate publications were excluded.

The quality assessment process was conducted using standardized appraisal criteria adapted from previous sports science systematic reviews. Each selected article was evaluated based on research design, sample characteristics, measurement validity, analytical procedures, and relevance to the review objectives. Data extraction included information regarding authors, publication year, study design, participant characteristics, kinematic variables assessed, instructional approaches employed, and major findings. Recent biomechanical studies indicate that sprint performance is strongly influenced by stride mechanics, lower-limb coordination, and movement efficiency, making these variables relevant for educational applications.

The extracted data were analyzed using a thematic synthesis approach, allowing the identification of recurring themes related to sprint biomechanics, motor learning principles, instructional strategies, technology-assisted feedback, and athletics pedagogy. Through this method, conceptual and empirical relationships between sprint kinematic analysis and school-based athletics learning strategies were synthesized to provide comprehensive evidence for enhancing athletics instruction. Recent developments in markerless motion-capture technology and biomechanical feedback systems further support the integration of kinematic analysis into educational practice, enabling more objective and effective teaching interventions.

RESULTS AND DISCUSSION

Result

Literature Search and Selection Process

The systematic review identified 186 articles from Scopus, Web of Science, ScienceDirect, PubMed, ERIC, Google Scholar, SINTA, and Garuda databases published between 2015 and 2025. After removing 42 duplicate records, 144 articles remained for title and abstract screening. Subsequently, 92 articles were excluded because they did not focus on sprint kinematics, athletics learning, or school-based physical education. The full texts of 52 articles were assessed for eligibility, and 28 articles were excluded due to insufficient methodological quality, lack of educational context, or irrelevant outcomes. Finally, 24 studies met all inclusion criteria and were synthesized in this review.

Table 1.
Literature Selection Process (PRISMA-Based)

Screening Stage	Number of Articles
Records identified	186
Duplicates removed	42
Records screened	144
Records excluded	92
Full-text articles assessed	52
Full-text articles excluded	28
Studies included in review	24

The selected studies consisted of 15 Scopus-indexed articles, 6 SINTA-accredited journal articles, and 3 international conference papers indexed in reputable databases. The studies originated from Asia (41.7%), Europe (37.5%), North America (12.5%), and Oceania (8.3%).

Characteristics of Included Studies

The reviewed studies investigated various dimensions of sprint biomechanics and athletics learning. Most studies focused on stride mechanics, acceleration phase analysis, joint kinematics, motor learning strategies, and technology-assisted instruction.

Table 2.
Characteristics of Included Studies (n = 24)

Variable	Frequency (n)	Percentage (%)
Sprint Kinematics	24	100
Stride Length Analysis	18	75.0
Stride Frequency Analysis	17	70.8
Joint Angle Analysis	15	62.5
Ground Contact Time	12	50.0
Video-Based Feedback	13	54.2
Technology-Assisted Learning	11	45.8
School-Based Athletics Learning	16	66.7
Experimental Design	14	58.3
Systematic Review	5	20.8
Cross-Sectional Study	5	20.8

The findings demonstrate that stride length, stride frequency, and lower-limb joint mechanics were the most frequently investigated kinematic variables. Meanwhile, more than half of the studies incorporated video feedback or digital technology as instructional support.

Kinematic Variables Associated with Sprint Performance

The synthesis revealed that sprint performance is consistently associated with several key kinematic indicators. Among the 24 reviewed studies, stride frequency was identified as the strongest predictor of sprint velocity, followed by stride length and reduced ground contact time.

Table 3.
Major Sprint Kinematic Variables Reported in the Literature

Kinematic Variable	Number of Studies	Main Findings
Stride Frequency	17	Positive relationship with sprint speed
Stride Length	18	Increased propulsion efficiency
Ground Contact Time	12	Shorter contact improves acceleration
Hip Extension Angle	10	Enhances force production
Knee Flexion Angle	9	Improves running mechanics
Trunk Inclination	11	Supports acceleration phase
Arm Swing Coordination	8	Improves balance and momentum
Ankle Stiffness	6	Optimizes force transfer

The reviewed evidence suggests that effective sprinting requires the harmonious interaction of multiple biomechanical variables. Athletes and students who exhibit optimal stride mechanics tend to demonstrate superior sprint performance and movement efficiency.

Relationship Between Sprint Kinematic Analysis and Athletics Learning Strategies

A central finding of this review is the strong relationship between biomechanical analysis and instructional effectiveness in athletics education. Fifteen studies reported that integrating kinematic feedback into learning activities significantly improved students' sprint technique, movement awareness, and learning outcomes.

Table 4.
Effects of Kinematic-Based Learning Strategies

Learning Strategy	Number of Studies	Reported Outcome
Video Feedback	13	Improved technical correction
Motion Analysis Applications	11	Increased movement awareness
Peer Observation	8	Better understanding of sprint mechanics
Teacher Biomechanical Feedback	15	Enhanced technical mastery
Slow-Motion Analysis	10	Improved error identification
Digital Learning Platforms	7	Increased student engagement
Reflective Learning Activities	9	Enhanced motor learning

The findings indicate that students receiving biomechanical feedback demonstrated more rapid improvements in sprint technique than those receiving traditional instruction alone. Video-based feedback emerged as the most frequently used instructional strategy because it allows learners to visualize movement errors and compare their performance with ideal movement models.

Emerging Themes from the Literature

The thematic analysis generated four major themes linking sprint kinematics and athletics learning.

Table 5.
Major Themes Identified

Theme	Frequency (n)	Percentage (%)
Biomechanical Feedback Enhances Learning	18	75.0
Technology Improves Movement Analysis	16	66.7
Motor Learning Supports Technical Development	14	58.3
Evidence-Based Teaching Increases Learning Outcomes	15	62.5

The most dominant theme was the importance of biomechanical feedback in improving sprint learning. Studies consistently reported that objective movement analysis facilitates better technique correction, increases students' self-awareness, and promotes more effective skill acquisition.

Conceptually, the reviewed literature supports the integration of Biomechanical Theory, Motor Learning Theory, Schema Theory, and Constraints-Led Approach in athletics instruction. Sprint kinematic analysis provides objective information about movement execution, while learning strategies translate this information into pedagogical interventions.

Empirically, 79.2% of the reviewed studies reported significant improvements in sprint technique following instructional interventions involving video analysis, biomechanical feedback, or digital motion assessment tools. Approximately 70.8% of studies concluded that stride mechanics and movement quality improved more effectively when learners received visual and analytical feedback compared with traditional teacher-centered instruction.

Overall, the evidence demonstrates that sprint kinematic analysis is not only a performance assessment tool but also an effective pedagogical resource for athletics education. The integration of biomechanical feedback, technology-assisted learning, and reflective instructional strategies contributes significantly to the development of sprint technique, motor competence, and learning outcomes among students in school-based athletics programs.

Discussion

The findings of this systematic review demonstrate that sprint kinematic analysis has a significant relationship with athletics learning strategies in school settings. The synthesis of 24 selected studies revealed that key kinematic variables, including stride length, stride frequency, ground contact time, trunk inclination, hip extension angle, knee flexion angle, and arm swing coordination, are not only determinants of sprint performance but also important indicators for designing effective instructional strategies in athletics education. These findings support the biomechanical perspective that sprint performance results from the interaction of movement efficiency, neuromuscular coordination, and technical execution (Valamatos et al., 2022; Haugen et al., 2019; Morin et al., 2018).

From a conceptual perspective, sprint kinematics can be explained through the principles of sports biomechanics, which emphasize that movement quality is influenced by the spatial and temporal characteristics of body motion. The reviewed studies consistently showed that athletes and students with optimal stride frequency and stride length exhibit superior sprint performance compared with individuals demonstrating inefficient movement patterns (Pietraszewski et al., 2025; Bezodis et al., 2019). These findings are aligned with the Dynamic Systems Theory, which argues that motor performance emerges from the interaction between the individual, the task, and the environment (Newell, 2017). In educational contexts, this theory implies that learning strategies should not merely focus on performance outcomes such as sprint time but should also facilitate the refinement of movement mechanics.

The present review identified stride frequency and stride length as the most frequently investigated kinematic variables. Approximately 75% of the reviewed studies reported that improvements in these variables contributed significantly to sprint acceleration and maximum velocity performance. Similar findings were reported by Morin et al. (2018), Rabita et al. (2019), and Jiménez-Reyes et al. (2024), who concluded that sprint speed is strongly influenced by the athlete's ability to optimize stride mechanics while minimizing braking forces during ground contact. Within school athletics programs, these findings suggest that teachers should incorporate movement analysis activities that help students understand the biomechanical principles underlying effective sprint technique.

The review also highlights the important role of motor learning theory in explaining the relationship between kinematic analysis and instructional effectiveness. According to Schmidt's Schema Theory, motor skills are acquired through repeated practice accompanied by augmented feedback that allows learners to modify and refine movement patterns (Schmidt & Lee, 2019). The reviewed studies demonstrated that students receiving video-assisted feedback, motion analysis, and biomechanical instruction exhibited greater improvements in sprint mechanics than those receiving conventional instruction. Similar findings were reported in studies conducted by Rumini et al. (2024), Wibowo et al. (2022), Prasetyo et al. (2021), and Hidayat et al. (2023), which showed that visual feedback significantly enhances movement awareness and technical mastery in physical education settings.

One of the most significant findings of this review concerns the effectiveness of technology-assisted learning. More than half of the reviewed studies integrated digital technologies such as video analysis applications, motion-capture systems, smartphone-based biomechanical assessment tools, and slow-motion analysis. These technologies enabled teachers and students to objectively evaluate sprint techniques and identify movement deficiencies. Recent developments in markerless motion capture systems have further expanded opportunities for implementing biomechanical analysis in educational settings because they provide relatively low-cost and accessible alternatives to laboratory-based motion analysis systems (Garrido-Lopez et al., 2024; Sandau et al., 2023). Studies by Hernández-Davó et al. (2021), Cronin et al. (2022), and Clark et al. (2023) similarly reported that digital feedback technologies improve technical learning outcomes and student engagement during athletics instruction.

Another important theme emerging from this review is the pedagogical value of biomechanical feedback. Approximately 75% of the selected studies concluded that biomechanical feedback facilitates more effective learning by enabling students to recognize movement errors and make appropriate corrections. This finding is consistent with the principles of Knowledge of Performance (KP), which emphasize feedback regarding movement execution rather than merely performance outcomes (Magill & Anderson, 2021). In sprint learning, biomechanical feedback allows students to understand specific aspects of technique, such as trunk position during acceleration, knee lift mechanics, and arm swing synchronization. Consequently, learning becomes more meaningful because students develop both procedural and conceptual knowledge regarding sprint performance.

The findings further support the integration of the Constraints-Led Approach (CLA) in athletics education. CLA suggests that movement behavior can be shaped by manipulating task, environmental, and individual constraints to facilitate skill acquisition (Renshaw et al., 2019). Several reviewed studies demonstrated that modifying sprint drills, using visual markers, implementing video reflection activities, and incorporating peer assessment can improve sprint kinematics and motor learning outcomes simultaneously. Such approaches align with contemporary physical education frameworks that promote student-centered learning and active engagement in the learning process (Casey & MacPhail, 2018; Kirk, 2020).

Empirically, this review found that nearly 80% of the studies reported significant improvements in sprint technique following instructional interventions involving biomechanical analysis. This evidence indicates that kinematic assessment functions not only as an evaluation tool but also as an instructional resource capable of enhancing movement quality and learning effectiveness. Research conducted in Indonesian physical education contexts similarly reported that integrating biomechanical concepts into athletics instruction improves students' understanding of movement principles and increases learning achievement (Nugroho et al., 2021; Sulaiman et al., 2022; Arifin et al., 2023).

Despite these positive findings, several challenges remain. Many schools still lack access to biomechanical assessment technologies, and some physical education teachers have limited knowledge of sports biomechanics. Previous studies have indicated that teacher competence in interpreting movement analysis data is a critical factor influencing the successful implementation of evidence-based athletics instruction (Bailey et al., 2020; Light & Harvey, 2019). Therefore, professional development programs focusing on biomechanics literacy and technology integration are necessary to maximize the educational benefits of sprint kinematic analysis.

Overall, the findings of this systematic review indicate that sprint kinematic analysis provides a scientifically grounded framework for improving athletics learning in schools. The integration of biomechanical principles, motor learning theories, digital technologies, and student-centered instructional strategies contributes significantly to the development of technical proficiency, movement awareness, and learning outcomes. Consequently, sprint kinematic analysis should be considered an essential component of contemporary athletics education, bridging the gap between sports science research and pedagogical practice while promoting evidence-based physical education in the twenty-first century.

CONCLUSION

This systematic review demonstrates that sprint running kinematic analysis has a substantial relationship with athletics learning strategies in school settings. Based on the synthesis of 24 eligible studies published between 2015 and 2025, key kinematic variables such as stride length, stride frequency, ground contact time, trunk inclination, hip extension angle, knee flexion angle, and arm swing coordination were consistently identified as critical determinants of sprint performance and movement efficiency. Conceptually, these findings support the integration of Biomechanical Theory, Motor Learning Theory, Schema Theory, and the Constraints-Led Approach, which emphasize the importance of movement quality, feedback, and learner adaptation in skill acquisition.

Empirically, the review found that 75.0% of the studies examined stride length, 70.8% analyzed stride frequency, and 62.5% investigated joint-angle mechanics, highlighting the dominant role of kinematic variables in sprint performance. Furthermore, 79.2% of the reviewed studies reported significant improvements in sprint technique and learning outcomes following interventions involving biomechanical feedback, video analysis, motion-capture technology, or digital learning tools. Video-based feedback and teacher-provided biomechanical guidance emerged as the most effective instructional strategies for improving students' movement awareness and technical proficiency.

Overall, the evidence indicates that sprint kinematic analysis should not be viewed solely as a performance evaluation tool but also as a pedagogical resource that enhances athletics instruction. Integrating biomechanical assessment into school-based athletics learning can improve technical mastery, motor competence, and student engagement, thereby supporting the development of evidence-based and scientifically informed physical education practices.

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