



A Review of Karate from a Biomechanical Perspective and Its Potential as a Medium for Physics Instruction

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Abstract

Karate biomechanics, as a field, examines human body movement through a scientific lens and is inherently tied to various physics concepts, particularly those in mechanics. Yet the potential of Karate biomechanics research as a medium for physics instruction remains largely underexplored. This study sets out to trace the development of both Karate biomechanics research and physics education research, while also evaluating the prospective use of the former as a teaching tool in physics. We employed a bibliometric analysis combined with a literature review. Publication data were drawn from the Scopus database and processed with VOSviewer software to map keyword networks, research trends, and cross-topic relationships. The findings indicate that publications in both Karate biomechanics and physics education have grown at a considerable pace ($n = 643$). The keyword network visualization reveals points of convergence between the two fields through themes like motion, kinematics, movement analysis, and phenomenon-based learning. Our literature review suggests that Karate biomechanics can serve as a viable instructional medium, precisely because it presents real, measurable, and easily observable motion phenomena suitable for explaining a range of mechanics concepts. The study yields three main findings: (a) research in Karate biomechanics has grown substantially, with core interests centered on bodily motion analysis, kinematics, physical performance, and the use of motion-capture technologies; (b) physics education research that integrates sports and martial arts has shown rapid productivity gains, emphasizing conceptual understanding, student engagement, inquiry- and project-based approaches, along with STEM and educational technology integration; (c) Karate biomechanics clearly has potential as a physics learning medium. The very fact that it offers tangible, quantifiable, and readily observable motion phenomena suggests that integrating Karate biomechanics into physics instruction could foster more meaningful and context-rich learning experiences for students.

Keywords: Bibliometric analysis; Karate biomechanics; Physics education; Instructional media

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INTRODUCTION

Scientific development has increasingly positioned the study of human movement as a central concern across various sports disciplines. Analysis of movement patterns offers the scientific groundwork for understanding how the body generates, modulates, and transmits force during physical activity (Huang et al., 2025). Such information is drawn upon to enhance athletic performance, design more effective training programs, assess technical quality, and support injury prevention efforts. One widely used approach to examining these aspects is biomechanics, a branch of science that applies mechanical principles to the quantitative analysis of human movement characteristics (Yan et al., 2022). Technological advances from motion capture systems and force plates to inertial measurement units (IMUs) and wearable sensors have steadily broadened the scope of biomechanics, enabling the collection of accurate data on movement dynamics across a diverse array of sporting activities (Goethel et al., 2023; Molinaro et al., 2026).

Karate is a martial art distinguished by its rapid, structured movements and the high degree of precision demanded in every technique (Robalino et al., 2025). The execution of strikes, kicks, and positional shifts unfolds through complex inter-segmental coordination, such that movement effectiveness is shaped by balance, postural control, the sequencing of muscle activation, and the efficiency of force transfer across different phases of motion. These very characteristics position Karate as a relevant object of biomechanical inquiry, since each component of movement lends itself to objective analysis through various mechanical parameters (Cottone et al., 2026; Mohammadalizadeh et al., 2024). Some evidence findings from Karate biomechanics serve as a foundational basis for scholarly examination, affording a more profound understanding of technical quality while simultaneously supplying a scientific underpinning for athlete performance development and the evaluation of training procedures (Molinaro et al., 2026). That circumstances have encouraged an increasing volume of research that utilizes biomechanical approaches to investigate various fundamental Karate techniques more systematically.

Attention to Karate biomechanics continues to grow alongside the evolving need for more objective movement analysis in martial arts (Mustapha et al., 2025; Stadler et al., 2026). Various studies have examined the biomechanical characteristics of fundamental Karate techniques in order to understand the factors that influence movement effectiveness. These inquiries cover biomechanical analyses of the *gyaku tsuki* punch and the *mae geri* kick, directed at evaluating movement patterns, speed, balance, inter-segmental coordination, and the mechanisms of force generation during technique execution (Błaszczyszyn et al., 2019; Goethel et al., 2023). A number of studies have also investigated the relationship between biomechanical characteristics and athlete performance, drawing on measurements of muscle activation, neuromuscular capacity, postural stability, joint mobility, reaction time, and factors related to injury risk (Brito et al., 2025; Zintel et al., 2026). From that developments indicate that Karate biomechanics research has evolved from mere technical description toward a more comprehensive effort to understand movement mechanisms, serving as a foundation for performance enhancement and training effectiveness.

The progress of Karate biomechanics research has been further supported by technological advances that enable more accurate and efficient movement measurement. The deployment of motion capture systems, force plates, inertial measurement units (IMUs), wearable sensors, and various computer-based analytical approaches has expanded the capacity of researchers to obtain biomechanical data at increasingly higher resolutions (Giardullo et al., 2025; Kaczmarek et al., 2026; Kato & Yamagiwa, 2021). These innovations have opened up opportunities to observe movement characteristics across various training and competitive conditions with greater depth, while simultaneously enhancing the validity of analytical outcomes (Leshko et al., 2025). This methodological evolution shows that Karate biomechanics research no longer rests on a single type of instrument, but rather continues to adapt to advances in movement measurement and analysis technology (Moriya et al., 2026). Such conditions indicate that the field of Karate biomechanics is dynamically evolving and steadily broadening its scope with respect to both methodological approaches and research instruments.

Biomechanics shares a close conceptual affinity with the fundamental principles of mechanics taught in physics, such that any sporting movement can serve as a representation of genuine scientific phenomena (Salibay, 2026). Movements in Karate techniques, such as punches, kicks, positional shifts, and the process of maintaining balance, involve various principles of physics, including force, work, energy, impulse, momentum, torque, center of mass, and the laws of motion (Sikdar et al., 2026). The biomechanical approach allows each of these concepts to be analyzed quantitatively through the measurement of various mechanical parameters, so that the relationship between physical theory and movement phenomena can be explained in more concrete terms. These characteristics show that Karate techniques have

potential as a medium for representing mechanics concepts in situations that are close to everyday life. A number of studies in other sports and martial arts demonstrate that sensor-based movement analysis can visualize physics concepts scientifically and support learning that is oriented toward real phenomena (Błaszczyszyn et al., 2019).

The use of real phenomena as learning resources has become a notable trend in the development of physics instruction, as it helps students connect abstract concepts with events that can be directly observed. Various studies report that context-based learning through sporting activities, traditional games, virtual laboratories, mobile technology, virtual reality, and STEM approaches contributes to improved conceptual understanding, scientific thinking skills, and student engagement throughout the learning process (Anas et al., 2026; Caner, 2026). Such developments indicate that the use of everyday phenomena is gaining increasing attention as a means of explaining physics concepts in a more meaningful way (Şengül & Karabacak, 2026). Nevertheless, studies that integrate findings from Karate biomechanics research into physics learning resources remain relatively scarce. Most Karate biomechanics investigations are oriented toward athletic performance enhancement, while physics education research has been more concerned with developing models, media, or instructional strategies without drawing upon biomechanical analyses of Karate as scientific representations of mechanics concepts (Mustapha et al., 2025; Robalino et al., 2025). This situation indicates that the linkage between developments in Karate biomechanics research and innovations in physics education still leaves room for more comprehensive examination.

Developments in Karate biomechanics research and innovations in physics education point toward positive trajectories in their respective domains. Biomechanics studies have generated a range of findings concerning movement characteristics, force generation mechanisms, muscle activation patterns, balance, and the increasingly sophisticated application of measurement technologies (Huang et al., 2025). Research in physics education has demonstrated a growing utilization of contextual phenomena as a vehicle for facilitating conceptual understanding in mechanics. (Corbi et al., 2019). Although the two fields have developed along independent paths, studies that connect findings from Karate biomechanics research with the development of physics instruction remain exceedingly limited. The available literature generally positions Karate as an object of sports science or exercise science inquiry, whereas physics education research has tended to concentrate on developing instructional models, media, and learning resources without drawing upon biomechanical analyses of Karate as a scientific foundation. This state of affairs points to a research gap, namely the absence of studies that map the development of Karate biomechanics research while simultaneously identifying its potential as a physics learning medium through bibliometric approaches and literature synthesis.

Based on this gap, the present study departs from earlier research by offering a different perspective. The novelty of this study lies in its integration of a bibliometric analysis of Karate biomechanics research development with a literature review that explores its prospective use as a physics learning medium. This dual approach affords a more comprehensive picture of research trajectories, dominant themes, and the opportunities for further inquiry at the intersection of sports biomechanics and physics education. Through this synthesis, the study is expected to make a conceptual contribution to the advancement of interdisciplinary research, while simultaneously broadening the range of alternative learning resources that draw upon movement phenomena as representations of mechanics concepts.

Based on the foregoing discussion, this study is directed toward addressing several questions, namely: (1) what is the trend of Karate biomechanics research over the period 2016–2026; (2) what are the developmental characteristics of Karate biomechanics research as revealed by bibliometric analysis; and (3) what is the extent to which findings from Karate biomechanics research can be utilized as a medium in physics instruction. These questions are formulated to provide a comprehensive understanding of the field's development while

simultaneously identifying opportunities for its application within educational contexts.

This study aims to analyze the trends and developmental characteristics of Karate biomechanics research during the 2016–2026 period through a bibliometric approach, and subsequently to examine the potential utilization of these research findings as a medium in physics instruction based on a synthesis of the literature. The findings are expected to contribute to the development of interdisciplinary inquiry at the intersection of sports biomechanics and physics education, while simultaneously serving as a reference for both researchers and educators in developing physics instruction that employs movement phenomena as contextual learning resources.

METHODS

Information Source

This study draws on the Scopus database as its primary source for gathering scientific literature. Scopus was selected on the grounds of its extensive publication coverage and its internationally accredited reputation. The platform indexes thousands of journals across a broad range of disciplines, from the natural sciences and technology to the social sciences and humanities. Its multidisciplinary character was a key consideration, given that the research topic touches on two distinct domains, sports biomechanics and physics education also therefore requires simultaneous access to literature from both fields (Nurhasana et al., 2026). Journals indexed within Scopus have generally undergone a rigorous selection process, so that the quality of the available articles can be scientifically accounted for. Another advantage of Scopus lies in its bibliographic data export feature, which allows researchers to download metadata including titles, author names, affiliations, abstracts, keywords, publication years, and reference lists in a variety of formats compatible with bibliometric analysis software such as VOSviewer.

The publication timeframe applied in the search covers the years 2016 to 2026. This ten-year window was selected on the basis that the period is deemed sufficiently representative to portray recent research developments. The advancement of motion measurement technologies and pedagogical approaches in science education has accelerated quite markedly over the past decade. Articles published prior to 2016 are likely to differ methodologically, particularly in terms of the instruments employed, and thus hold less relevance to current research conditions and challenges. This limitation is consistently applied to all articles retrieved, across both the Karate biomechanics cluster and the sports-assisted physics learning cluster, so that data consistency between the two clusters can be properly maintained.

Eligibility Criteria

Eligibility criteria were established in this study to filter the articles obtained from the initial search, such that only documents genuinely relevant and compliant with scientific standards would be carried forward for analysis. Four aspects define the inclusion criteria: publication within the 2016 to 2026 window; acceptance of journal articles only, whether original research or reviews; English as the language of publication; and complete bibliographic records, including titles, author names, affiliations, abstracts, keywords, and reference lists. Conversely, exclusion criteria were applied to remove documents falling outside these provisions, encompassing non-journal items (such as conference proceedings, books, book chapters, or editorial notes), articles lacking abstracts, and those which, upon title and abstract screening, proved unrelated to the research focus in either the Karate biomechanics cluster or the sports-assisted physics learning cluster. All of these criteria were implemented systematically and consistently to guarantee an objective and transparent selection process, ensuring that the resulting dataset is genuinely representative and of sufficient quality to address the proposed research questions.

Data Collection Procedure

This study employs a Systematic Literature Review (SLR) approach combined with

bibliometric analysis to examine the development of Karate biomechanics research and to explore its potential as a medium in physics instruction. The choice of this approach rests on its capacity to present a comprehensive overview of a field's developmental trajectory through the identification of publication characteristics, research themes, and cross-topic interconnections (Nurhasana et al., 2026). The information obtained from this mapping subsequently serves as a basis for the literature synthesis process, so that the relationship between Karate biomechanics studies and physics instruction can be interpreted in a systematic manner.

Figure 1 presents the research stages, commencing with topic determination and the formulation of a literature search strategy, followed by the article identification process through the Scopus database. The subsequent stage entails screening articles by publication year, document type, and language, until a collection of articles meeting the research criteria is obtained. All articles that pass the selection are then used as data sources in the bibliometric analysis and literature synthesis to address the research questions concerning trends in Karate biomechanics research, trends in sports-media-assisted physics learning research, and the potential of Karate as a medium in physics instruction.

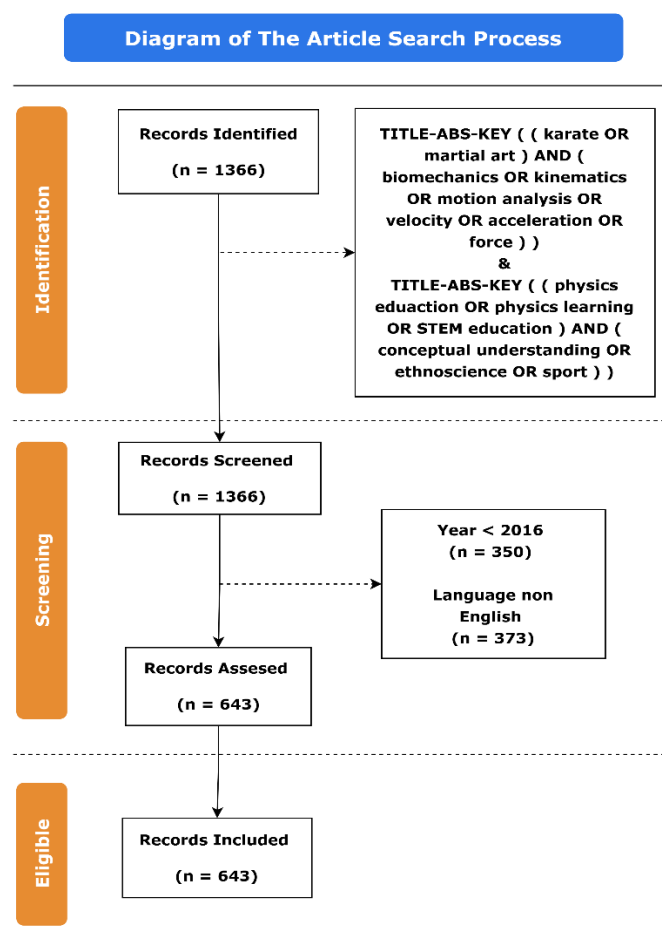


Figure 1. Research process flow

Research data were obtained through article searches in the Scopus database using the TITLE-ABS-KEY search field. The search strategy was constructed in two clusters aligned with the research focus, namely the Karate biomechanics cluster and the sports-media-assisted physics learning cluster. The first cluster employed keyword combinations relating to Karate, martial art, biomechanics, kinematics, motion analysis, velocity, acceleration, and force. The second cluster employed keyword combinations encompassing physics education, physics learning, STEM education, conceptual understanding, ethnoscience, and sport. The entire search process was restricted to English-language articles published during the 2016–2026

period, so that the data obtained would correspond to the research objectives.

The search in the Karate biomechanics cluster yielded 606 articles. This number was reduced to 443 after applying publication year restrictions, then to 344 after imposing criteria for document type (articles only) and English as the language of publication. The search in the sports-media-assisted physics learning cluster produced 760 articles, which subsequently became 573 after publication period restrictions and 299 after applying document type and language criteria. Based on the entire selection process, 643 articles were obtained for use as the dataset in this study.

Data Analysis

Bibliometric analysis was carried out with the assistance of VOSviewer software to map research development within each cluster based on publication characteristics, keyword interrelationships, and the connections among articles indexed in the Scopus database. The analytical procedure began with exporting bibliographic data from all articles meeting the selection criteria, followed by a data standardization process to ensure consistency in the information under analysis. The prepared dataset was then examined using bibliometric analysis software to generate research network visualizations, keyword co-occurrence patterns, and developmental tendencies in research themes during the 2016–2026 period. Findings from this analysis served as the basis for identifying research trends in both the Karate biomechanics cluster and the sports-media-assisted physics learning cluster, in accordance with the study objectives.

RESULTS AND DISCUSSION

Trends in Karate Biomechanics Research 2016–2026

The development of Karate biomechanics research over the period 2016 to 2026 showed a generally increasing trend, albeit with some fluctuations in certain years. As presented in Figure 2, the number of publications rose from 23 articles in 2016 to 25 in 2017 and 26 in 2018. The trend held steady in 2019 with the same number of publications, then increased again to 32 articles in 2020 and 34 in 2021. Following a slight decline to 31 articles in 2022 and 26 in 2023, research productivity rose markedly, reaching 47 articles in 2024 and 51 in 2025. Meanwhile, the number of publications recorded for 2026 stood at 23 articles. This decrease does not signal waning attention to Karate biomechanics research, but rather reflects the ongoing publication and indexing process, so that the data for 2026 do not yet fully represent the total articles expected to appear in that year.

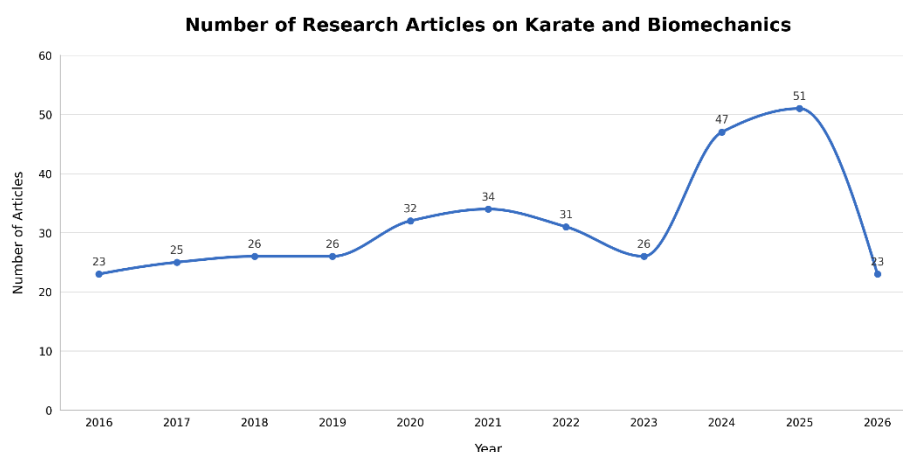


Figure 2. Annual Publication Counts for Karate and Biomechanics Research

The increasing productivity of publications in this area signals that Karate biomechanics is steadily gaining ground as a research field that attracts interest from a range of disciplines. Advances in motion analysis technologies, including motion capture, inertial measurement units (IMUs), electromyography (EMG), force plates, and computer vision and artificial

intelligence based approaches, have made it possible to measure biomechanical parameters with greater accuracy and objectivity (Merk & Resnick, 2021; Yan et al., 2022). These advancements have driven a shift in research orientation, moving from technical description toward quantitative analysis capable of elucidating movement characteristics, biomechanical efficiency, athletic performance, and injury mechanisms. Consequently, Karate biomechanics research is no longer perceived as a field confined to sports science, but has evolved into a multidisciplinary domain that integrates biomechanics, computer science, engineering, and health sciences to yield a more comprehensive understanding of human movement (Molinaro et al., 2026).

Table 1. Citation statistics for Karate and biomechanics research.

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2016	29,52	23	2,68	11
2017	28,48	25	2,85	10
2018	16,88	26	1,88	9
2019	17,12	26	2,14	8
2020	17,44	32	2,49	7
2021	15,94	34	2,66	6
2022	7,90	31	1,58	5
2023	7,73	26	1,93	4
2024	4,87	47	1,62	3
2025	2,37	51	1,19	2
2026	0,09	23	0,09	1

The rising volume of publications has been accompanied by changing scholarly impact, as reflected in the yearly citation statistics. According to Table 1, articles from 2016 show a MeanTCperArt of 29.52, dipping slightly to 28.48 in 2017. The average citation count then followed a fluctuating course, registering 16.88 in 2018, 17.12 in 2019, 17.44 in 2020, and 15.94 in 2021, before falling to 7.90 in 2022, 7.73 in 2023, 4.87 in 2024, 2.37 in 2025, and 0.09 in 2026. At the same time, the annual number of published articles has trended upward, with especially notable totals in 2024 and 2025 at 47 and 51 articles, respectively. This divergence between publication productivity and average citation rates suggests that a larger output does not automatically translate into higher citation impact. Papers published earlier benefit from a longer citation window, with 11 years available for the 2016 cohort and 10 years for 2017, giving them a greater chance of accumulating citations than newly released articles. The low citation counts for recent publications therefore reflect a short citation window more than they do any shortcoming in research quality.

Research Trends in Physics Instruction Incorporating Sports and Martial Arts 2016–2026

The development of research on physics learning incorporating sports and martial arts over the period 2016–2026 shows an upward trend with a more dynamic growth pattern compared to the early years of observation. As presented in Figure 3, the publication count rose from 8 articles in 2016 to 15 in 2017 and remained at the same level in 2018. The total then increased to 19 articles in 2019 before experiencing a slight dip to 14 in 2020. Research productivity resumed its upward course in 2021 and 2022 with 17 and 16 articles respectively, then experienced a fairly marked jump to 32 articles in 2023. Although it declined somewhat to 29 articles in 2024, the publication count surged sharply to reach 67 articles in 2025 and stayed at that same figure in 2026. This pattern suggests that the use of sports and martial arts as a context for physics learning has drawn increasing attention in recent years, particularly as learning approaches that emphasize contextual and phenomenon-based learning experiences have continued to gain ground.

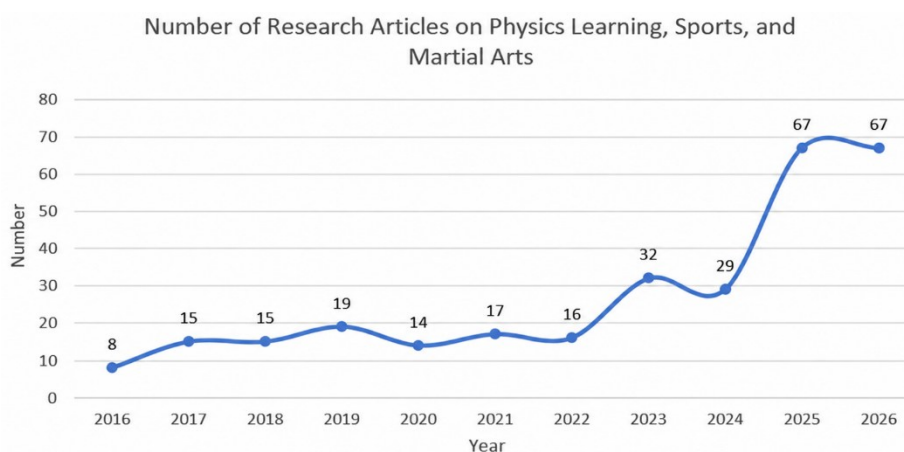


Figure 3. Annual Publication Counts for Physics Education Research

The rising productivity of publications in this area reflects a reorientation in physics education research, one that increasingly privileges authentic learning experiences over the abstract delivery of concepts. A range of studies have drawn on sports as a medium for representing mechanics concepts, precisely because sporting contexts can present physics phenomena that are directly observable, measurable, and amenable to scientific analysis (Hariyono et al., 2023; Mansyur et al., 2020). Developments in learning technologies, including interactive simulations, video analysis, virtual reality, augmented reality, and STEM-based as well as multiple representations approaches, have likewise broadened the scope of physical activity as a vehicle for building conceptual understanding (Kurbanbekov et al., 2025; Papalazarou et al., 2024). This state of affairs suggests that modern physics instruction is moving increasingly toward the integration of real phenomena with scientific representations, such that learners come to understand mathematical equations while also being able to connect these equations to events they encounter in daily life (Wirjawan et al., 2020).

Table 2. Annual Citation Statistics for Physics Education Research

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2016	72,75	8	6,61	11
2017	23,67	15	2,37	10
2018	18,73	15	2,08	9
2019	23,42	19	2,93	8
2020	17,86	14	2,55	7
2021	77,24	17	12,87	6
2022	12,06	16	2,41	5
2023	10,88	32	2,72	4
2024	7,97	29	2,66	3
2025	2,12	67	1,06	2
2026	0,28	67	0,28	1

The growing volume of publications is accompanied by variations in scholarly impact across different publication years. As shown in Table 2, articles from 2021 record the highest MeanTCperArt at 77.24, followed by the 2016 cohort at 72.75. Average citation counts then decline to 23.67 in 2017, 18.73 in 2018, 23.42 in 2019, 17.86 in 2020, 12.06 in 2022, 10.88 in 2023, 7.97 in 2024, 2.12 in 2025, and 0.28 in 2026. Although the number of publications rose markedly in 2025 and 2026, reaching 67 articles in both years, the average citation counts for these two years remain relatively low. This pattern is influenced by differences in citable years, with articles from 2016 having had 11 years to accumulate citations, whereas those from 2026 have been available for only one year. Thus the low citation figures for recent publications reflect a short citation window more than any deficiency in the quality of the work produced.

The Potential of Karate Biomechanics as a Medium for Physics Instruction

The potential of Karate biomechanics as a medium for physics instruction can be discerned through the relationships between human movement characteristics and the mechanics concepts that form an essential component of the physics curriculum (Alstein et al., 2021). A wide range of studies indicate that physics instruction becomes more effective when learners are given opportunities to observe real phenomena, conduct investigations, and connect the concepts they are studying with experiences that can be directly perceived (Asrizal et al., 2025; Organtini et al., 2025). On the other hand, Karate biomechanics research is concerned with the analysis of body movement using scientific approaches and measurement technologies capable of generating quantitative data on various aspects of human motion (Kim et al., 2024). That shared characteristic opens up opportunities to integrate findings from Karate biomechanics research into physics instruction, so that abstract concepts can be presented through phenomena that are more concrete and readily grasped by students (Fiedler et al., 2025; Organtini et al., 2025).

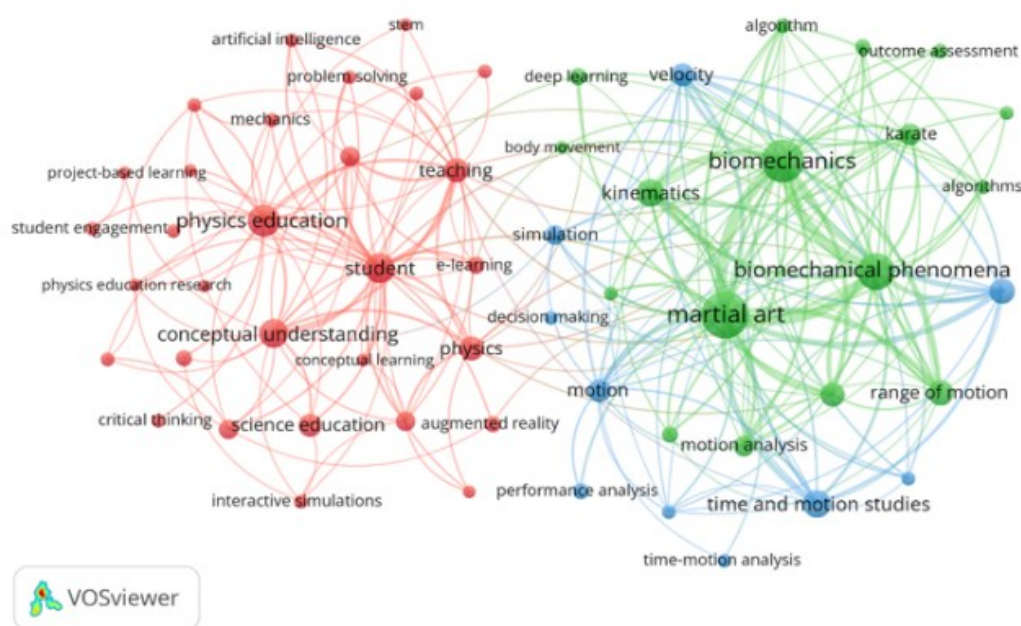


Figure 4. Keyword Network Map

As shown in Figure 4, the visualization of the keyword network reveals three main clusters that illustrate the connections between Karate biomechanics research and physics instruction. The red cluster is dominated by keywords relating to physics education, such as physics, physics education, student, conceptual understanding, conceptual learning, science education, critical thinking, problem solving, inquiry-based learning, project-based learning, interactive simulations, student engagement, artificial intelligence, and STEM. The presence of these terms suggests that the primary focus of research within this cluster is on the development of instructional strategies that enhance conceptual understanding, higher-order thinking skills, and learner engagement. In contrast, the green cluster is characterized by keywords including biomechanics, Karate, martial art, body movement, kinematics, velocity acceleration, motion analysis, physical performance, inertial sensor, algorithm, and deep learning. These terms reflect the emphasis of Karate biomechanics research on examining the characteristics of body movement through motion analysis and modern measurement technologies. The blue cluster, meanwhile, contains keywords such as motion, time-motion analysis, time and motion studies, reaction time, video recording, performance analysis, and decision making, which serve as a bridge between biomechanics research and the analysis of human movement.

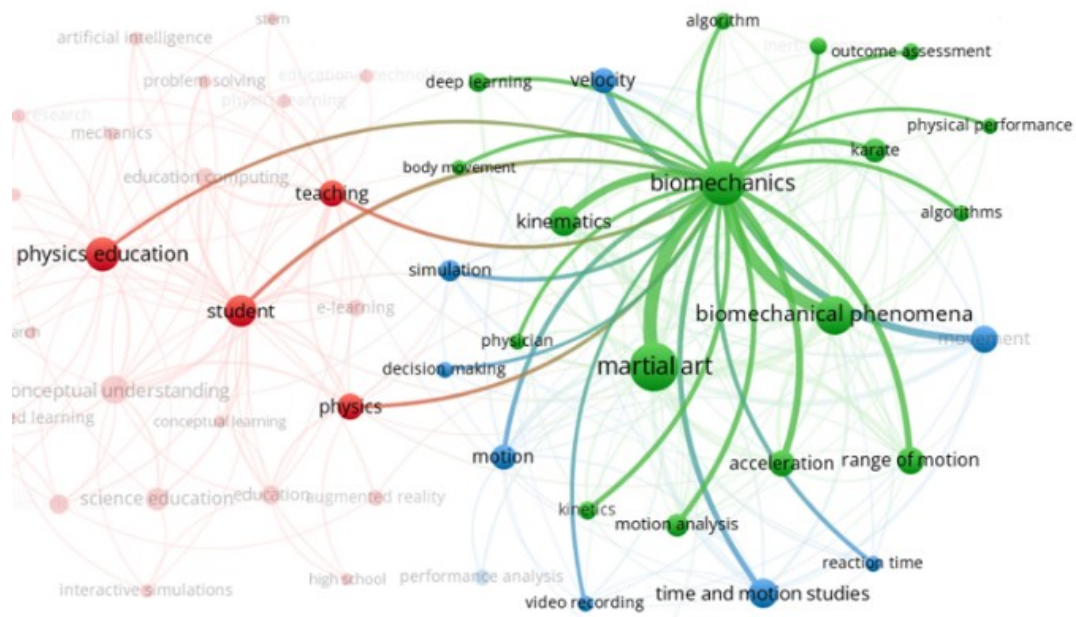


Figure 5. Keyword Network Map

The keyword network map displayed in Figure 5 offers a more detailed picture of where individual research topics sit within the intersection of Karate biomechanics and physics instruction, as well as the roles they play. The keyword biomechanics appears as the largest node and holds a central position in the network, reflecting its substantial interconnections with a range of other topics. Strong links are observable between biomechanics and terms such as biomechanical phenomena, martial art, Karate, kinematics, body movement, acceleration, physical performance, and algorithm. This configuration points to the trajectory of Karate biomechanics research, which advances through investigations of bodily motion underpinned by kinematic analysis and the use of movement measurement technologies. The close coupling of biomechanics and kinematics further suggests that motion constitutes the primary research focus; accordingly, findings from biomechanical studies hold potential for elucidating physics concepts tied to position, displacement, velocity, and acceleration.

Discussion

The present study aimed to map publication developments in both Karate biomechanics and physics education, while concurrently exploring the potential for their integration through bibliometric analysis and literature synthesis. Findings indicate that both fields have experienced positive growth, though with differing characteristics. As shown in Figure 2, publication productivity in Karate biomechanics rose consistently from 23 articles in 2016 to 51 articles in 2025, with a particularly sharp increase in 2024 and 2025. A similar upward trajectory is observed in physics education research incorporating sports, where Figure 3 reveals a very marked surge from 29 articles in 2024 to 67 articles in 2025. These two trends do not exist in isolation, but rather reflect a broader paradigmatic shift taking place within each discipline. Advances in movement measurement technology and the growing pedagogical demand for authentic learning experiences stand out as the principal driving forces behind these dynamics (Molinaro et al., 2026). Methodological shifts often serve as a catalyst for substantive transformation within a given field of inquiry (Goethel et al., 2023).

The increase in Karate biomechanics publications during the 2024 to 2025 period, as shown in Figure 2, did not occur by chance. Advances in motion measurement technologies, including motion capture, inertial measurement units (IMUs), and wearable sensors, have opened up opportunities for researchers to obtain kinematic and kinetic data at levels of accuracy previously beyond reach (Błaszczyzyn et al., 2019). Yet the data in Table 1 indicate that the average citations per article (MeanTCperArt) actually declined from 29.52 in 2016 to

2.37 in 2025, even as the number of articles rose sharply. This phenomenon reflects the effect of citable years, whereby older articles have a greater chance of being cited than newly published ones (Yan et al., 2022). In other words, the low citation counts in recent years reflect not inferior research quality, but rather the limited window of time available for new articles to gain scholarly recognition. Methodological advances that have driven a shift in research orientation, from mere technical description toward in-depth quantitative analysis of force generation mechanisms and neuromuscular responses in athletes, actually point to the growing maturity of Karate biomechanics as a field of study (Merk & Resnick, 2021). In addition, the growing interest in multidisciplinary approaches that integrate biomechanics with computer science, engineering, and health sciences has further consolidated the position of Karate biomechanics as a dynamic field relevant to a variety of scientific disciplines.

A similar dynamic is observable in physics education research incorporating sports. Figure 3 shows a very substantial jump in publication counts from 29 articles in 2024 to 67 articles in 2025, indicating that contextual approaches are gaining increasing acceptance within the development of physics pedagogy. Researchers have begun to recognize that instruction connecting abstract concepts with real phenomena close to learners' everyday lives has a greater impact on conceptual understanding than conventional deductive methods (Hariyono et al., 2023). Table 2 reinforces this finding by showing that although publication numbers increased dramatically, the average citation count per article in 2025 stood at only 2.12, which once again points to the influence of a short citation window. The use of sports as an instructional medium enables students to observe directly how the laws of mechanics operate in human body movement (Mansyur et al., 2020). This approach is consistent with the recommendations of various studies that emphasize the importance of authentic learning experiences in building deep and durable understanding (Papalazarou et al., 2024). Thus the upward trend in publications in this field does not arise solely from the popularity of the topic; responsiveness to pedagogical demands that are increasingly learner-centered also serves as an equally important driver. Authentic inquiry-based learning has been shown to significantly enhance student engagement and conceptual understanding (Fernandez, 2017).

The relationship between Karate biomechanics and physics instruction becomes clearer when examined through the keyword network visualization in Figure 4. The analysis reveals three main interacting clusters: a red cluster dominated by physics education keywords (physics, physics education, conceptual understanding, inquiry-based learning), a green cluster encompassing sports biomechanics (biomechanics, Karate, kinematics, motion analysis), and a blue cluster that serves as a bridge through terms such as motion, time-motion analysis, and video recording. The presence of kinematics, motion analysis, and simulation as linking terms between clusters suggests an epistemological common ground between the study of human movement and mechanics concepts (Kim et al., 2024). Both fields rely on measurement, data analysis, and the modeling of physical phenomena. Figure 5 reinforces the central position of the keyword biomechanics, which shows strong connections to kinematics, body movement, acceleration, and physical performance. This common ground provides a solid foundation for integrating findings from Karate biomechanics research into physics instruction. Effective physics teaching requires representations of phenomena that can be directly observed and measured (Organtini et al., 2025), while Karate biomechanics research supplies exactly that kind of data in abundance through various measurable movement parameters (Fiedler et al., 2025). In other words, the relevance of Karate biomechanics is not confined to athletic concerns; its pedagogical potential is considerable and remains largely underexplored. Moreover, the absence of keywords specifically referring to Karate within the physics education cluster indicates that integration between the two fields still constitutes a wide-open research gap.

The potential for this integration becomes even more tangible when examined from a conceptual standpoint. Movements in Karate, such as the *gyaku tsuki* punch, the *mae geri* kick,

or various stances, involve a range of physics principles traditionally taught in schools. Analysis of punch velocity, impact force, changes in momentum, torque generated from hip rotation, and postural balance across different stances can elucidate concepts such as impulse, angular momentum, center of mass, and the equilibrium of rigid bodies (Robalino et al., 2025). Research conducted by Stadler et al. (2026) demonstrates that striking techniques like punches and kicks can generate forces reaching several thousand Newtons, which could serve as raw data for laboratory activities or student science projects. Learners might be guided to observe movement videos, measure motion parameters using simple devices such as smartphones equipped with the phyphox application, or even analyze data from published research (Mustapha et al., 2025). Enhanced conceptual understanding occurs alongside the development of critical and investigative thinking skills through activities of this kind. Approaches involving observation and analysis of real phenomena have been shown to be significantly more effective in building conceptual understanding than traditional lecture methods (Bigozzi et al., 2018). Karate biomechanics thus offers a living laboratory rich in physical phenomena ready for student exploration, while also bridging the gap between abstract theory and concrete experience.

The relevance of integrating Karate biomechanics into physics instruction is strengthened by its alignment with modern pedagogical approaches that appear in the red cluster of Figure 4, such as inquiry-based learning, project-based learning, and STEM education. These approaches emphasize investigative processes, problem-solving, and active learner engagement in constructing knowledge. Analyzing Karate movements from a physics perspective can be designed as a challenging yet enjoyable scientific project (Corbi et al., 2019). Learners might identify problems, formulate hypotheses, gather data, analyze results, and draw conclusions grounded in empirical evidence. This approach is consistent with findings that STEM and project-based learning can meaningfully enhance student engagement (Anas et al., 2026). The use of technologies such as video analysis, interactive simulations, or smartphone-based applications can enrich the learning experience and visualize concepts that are difficult to grasp through text alone (Wirjawan et al., 2020). This is particularly significant given that the results shown in Figures 4 and 5 place keywords like simulation and interactive simulations within the physics education cluster, indicating that technology holds an important role in contemporary physics instruction. The alignment between the potential of Karate biomechanics and the demands of modern pedagogy makes this integration an innovative alternative that is at once contextual and relevant to the current trajectory of physics education (Salibay, 2026).

Nevertheless, this study carries a number of limitations that must be acknowledged. The reliance on a single database, Scopus, means that articles indexed on other platforms such as Web of Science or Google Scholar were not included in the analysis. Furthermore, the English language restriction applied in the eligibility criteria resulted in the exclusion of articles in other languages that might have made significant contributions to the topic. These limitations, however, do not compromise the validity of the main findings, given Scopus's high reputation and broad coverage, which provide sufficient information for evaluating research within the desired scope of the field (Nurhasana et al., 2026). On the other hand, the literature synthesis nature of this study means that the findings remain conceptual and have not been empirically tested in actual learning environments. Further research that develops and tests the effectiveness of physics learning media based on Karate biomechanics is therefore urgently needed to provide empirical evidence supporting the theoretical claims presented here (Şengül & Karabacak, 2026). Such studies would constitute an important step toward bridging the gap between bibliometric analysis and pedagogical implementation in practice, as suggested by earlier research indicating that the development of locally grounded learning media requires empirical trials to ascertain their effectiveness (Damarsha et al., 2025).

Overall, this study offers a conceptual contribution to the development of

interdisciplinary inquiry at the intersection of sports biomechanics and physics education. The findings from bibliometric analysis and literature synthesis indicate that Karate biomechanics possesses a solid theoretical foundation for use as a contextual and meaningful learning medium. The interconnectedness of research themes visible in Figures 4 and 5, the shared scientific approach between biomechanics and physics, and the alignment with modern pedagogical demands reflected in the publication trends shown in Figure 3 all serve as pillars reinforcing the potential of this integration. Thus the study maps the existing research landscape while simultaneously opening pathways for further exploration into how human movement phenomena might be harnessed to explain physics concepts in ways that are more concrete and engaging for learners (Yang et al., 2023; Zoya et al., 2026). It is hoped that this integration can become one innovative alternative for creating deeper learning experiences relevant to everyday life, while also contributing to cultural preservation efforts through education.

CONCLUSION

The bibliometric analysis reveals that research in both Karate biomechanics and physics education has progressed at a considerable pace, supported by a diverse and continually expanding array of research themes. Studies in Karate biomechanics have largely concentrated on body movement analysis, kinematics, physical performance, and the application of motion measurement technologies, whereas physics education research has tended to emphasize conceptual understanding, student engagement, inquiry-based learning, project-based learning, STEM, and the use of educational technology. The keyword network visualization shows points of convergence between the two fields through a number of terms related to motion and physical analysis, indicating that the concepts examined in Karate biomechanics hold relevance to physics content, particularly in the area of mechanics.

The findings of this study, obtained through bibliometric analysis and literature synthesis of 643 Scopus-indexed articles over the 2016–2026 period, indicate that (a) Karate biomechanics research during this period experienced significant growth, with primary emphasis on body movement analysis, kinematics, physical performance, and the utilization of motion measurement technologies, as reflected in increased publication productivity despite fluctuations in citation impact attributable to differences in citation availability periods; (b) research on physics instruction incorporating sports and martial arts over the same period also demonstrated rapid productivity gains, with emphasis on conceptual understanding, student engagement, inquiry-based and project-based learning, as well as STEM and educational technology integration, marked by a substantial surge in publication counts in recent years; and (c) based on the cross-topic connections identified through keyword network visualization, Karate biomechanics is potentially utilizable as a physics learning medium because it can present motion phenomena that are real, measurable, and readily observable, where various Karate techniques can be employed to explain a range of mechanics concepts through observation and data-based analysis activities, with motion analysis technologies further reinforcing this potential. The integration of Karate biomechanics and physics instruction may therefore serve as an innovative alternative for creating more meaningful learning experiences while simultaneously supporting the enhancement of conceptual understanding in physics.

RECOMMENDATION

This study still carries several limitations that should be taken into account when interpreting the results obtained. The analysis was focused on scientific publication data indexed in the database used, so there remains a possibility that it has not covered all relevant research on Karate biomechanics or physics instruction available from other sources. In addition, this inquiry was conducted through bibliometric approaches and literature synthesis, so the findings have not yet been supported by media development or direct testing in actual learning environments. This circumstance means that the effectiveness of Karate biomechanics

as a physics learning medium has not yet been substantiated through empirical data involving learners.

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AUTHOR CONTRIBUTIONS STATEMENT

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CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

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