Vol. 7, No. 1, 2026, pp. 352-366
DOI: https://doi.org/10.29210/992160

ELORA

Contents lists available at Elora Center

Lentera Negeri

Journal homepage: https://lentera.eloracenter.org/lentera

Wearable technologies, performance analytics, and athlete monitoring systems in beach volleyball: a systematic review

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Article Info

Article history:
Received Apr 12th, 2026
Revised May 20th, 2026
Accepted Jun 11th, 2026

Keyword:
Beach volleyball;
Athlete monitoring;
Wearable technology;
Performance analytics;
Digital sports system

ABSTRACT

This review by a systematic method was intended to integrate the present knowledge about wearable gadgets, tracking systems, and analytical methods used for the purpose of athlete performance and monitoring assessment in beach volleyball. The review was run in line with the PRISMA 2020 criteria. Based on its wide interdisciplinary coverage of sport science, biomechanics, engineering, computer science, and sports technology research areas, Scopus was chosen as the main database. Studies that included beach volleyball players or events and referred to wearable, sensor-based, tracking, physiological, or computational monitoring technologies were accepted. Study screening and data extraction were performed independently by two reviewers with a very good level of inter-rater agreement (Cohen's $\kappa = 0.87$). Out of 128 published studies between 1998 and 2026, 112 were included in the qualitative synthesis. Thematic analysis mapped four main research areas: wearable sensor validation and load monitoring, physiological and biochemical monitoring, computer-vision tracking systems, and machine-learning-based performance analytics. Concerning validity, Inertial Measurement Units (IMUs) were highly reliable for jump detection and external-load monitoring, while beach volleyball environment positional accuracy of Ultra-Wideband (UWB) systems topped that of GPS technologies. Machine-learning algorithms reached very high accuracy for action recognition, frequently above 95%, although small datasets were characteristic of most research. The data presented also make a strong case for wearable and analytical technologies integration as the base of evidence-based athlete monitoring, training program optimization, tactical player analysis, and performance management in beach volleyball. Investigations aiming at longitudinal monitoring, females and youth as athlete groups, and physiological, environmental, and artificial intelligent monitoring systems integration seem to be the most promising directions for future research.

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Introduction

From a simple pastime on the beach, beach volleyball has grown into one of the most physically demanding Olympic sports. Its Olympic debut in Atlanta, 1996, has set the stage for this sport to be investigated by science not only because of the unique environment factors (sand, sunlight, thermal stress), but also due to the dyadic team structure which leads to physiological and biomechanical challenges that are not found in any other team sport (Junge et al., 2009; Engebretsen et al., 2013). High-intensity, explosive movements such as jump serves, spike attacks, and defensive digs in beach volleyball, which is played on a very energy-absorbing sand surface, often over multiple sets, are not supported by rotational substitution systems as in indoor volleyball. This is a very special situation that leads to both players in a duo having to cover the whole 8 × 8 m court. Furthermore, detailed physical analysis has become a critical element of preparation for high performance at the elite level.

Most of the research in sport science, especially on beach volleyball performance, has been relying on notational analysis, video-based game observations, and subjective coach assessments to determine competition demands and training responses (Palao et al., 2015; Medeiros et al., 2014; Alvarado-Ruano & López-Martínez, 2022). These methods at least were to some extent capable of highlighting a few technical-tactical parameters like serve efficacy, reception quality, sideout percentages, rally structure, etc. On the other hand, they also come with certain limitations. For starters, they involve a substantial amount of manual coding, secondly cannot reveal physiological states of players in real-time and to cap it all, being retrospective, they are a hindrance for immediate coaching interventions. Now, electronic performance and tracking systems (EPTS) including wearable inertial measurement units (IMU), global navigation satellite systems (GNSS), ultra-wideband (UWB) local positioning, and photoplethysmographic heart rate sensors have started getting substituted the older ways producing continuous, objective, and multi-dimensional athlete monitoring at a high-frequency continuous monitoring capabilities (Marzano-Felisatti et al., 2024; Pino-Ortega et al., 2026).

Manual notational analysis and video observation have significant limitations, which is why wearable technologies and electronic performance tracking systems (EPTS) have been progressively used in team sports studies over the last ten years. In sports such as football, rugby, and basketball, EPTS are widely used to quantify external loads by means of GPS-derived metrics (distance, acceleration, deceleration, high-speed running) and to measure the internal load through heart rate monitoring. Miniaturized wearable microsensors have also been increasingly applied to quantify sport-specific movement patterns across a range of team sports, demonstrating the growing versatility and practical utility of these devices in field settings (Chambers et al., 2015). There are strong correlations between these metrics and match outcome, injury risk, and recovery status (Gabbett, 2016; Impellizzeri et al., 2004). However, the use of wearable sensors in beach volleyball comes with some issues: the sand greatly affects signal transmission for GPS and UWB systems, high ambient temperatures put thermal limitations on battery-operated devices, and the two-player court layout demands very accurate positioning at very small inter-player distances (Schleitzer et al., 2022; Pino-Ortega et al., 2026; Schmidt et al., 2021). Such sport-specific constraints require separate validation studies and creation of interpretation frameworks that cannot be simply borrowed from other sports.

Improvement in the wearable devices like miniaturized IMU sensors, high-frequency GPS, and stable UWB positioning systems have led to advance in sports analytics via computer vision and machine learning. For example, deep convolutional neural networks (CNNs) trained on continuous IMU data streams were able to recognize beach volleyball actions (serve, attack, defence, block) with very high accuracy (over 97%) and without the need for any human labeling (Kautz et al., 2017). A market basket analysis of positional tracking data revealed tactical patterns in beach volleyball, for example, how serve location affects reception efficiency and attack success (Wenninger et al., 2019). Other machine learning models such as random forests, support vector machines, and gradient-boosted classifiers have been also evaluated with beach volley datasets (Wenninger et al., 2020; Baca et al., 2009). Combining computer-vision player tracking and physiological monitoring provides an a promising area for applied sports analytics (Link, 2014; Gomez et al., 2014; Jiang et al., 2016). The framing of team sport performance through the lens of complex adaptive systems further supports the integration of multiple analytical technologies to capture emergent tactical and physiological patterns in beach volleyball (Ribeiro et al., 2017).

Past systematic reviews have covered topics nearly touching beach volleyball sports science, such as match analysis and game statistics (Medeiros et al., 2014), injury epidemiology (Jiménez-Olmedo & Penichet-Tomás, 2015), technical-tactical factors (Alvarado-Ruano & López-Martínez, 2022), and physical performance demands (Marzano-Felisatti et al., 2025). Still, none have thoroughly charted wearable technologies and performance analytics combined as a tracking paradigm. Coaches and practitioners require a unified evidence base for them to properly decide about the technology to be used, metrics to be chosen, and data-interpretation methods. Furthermore, the bibliometric footprint of beach volleyball sport technology research has been mainly restricted to Brazil, Germany, and Spain, which leads to the question of whether the results from these countries are applicable to other nations (Nunes et al., 2020; Natali et al., 2019).

Perhaps the largest discrepancy is figuring out how athlete readiness or fatigue can be accurately evaluated in the context of beach volleyball. Some physical performance indicators have been tested on collegiate and elite athletes (Bozzini et al., 2021; Tometz et al., 2022; Hank et al., 2024), however, the connection between these metrics and perceived exertion, recovery biomarkers, and performance outcomes has not been entirely researched. Introduction of environmental factors makes it even more difficult, as these factors are absent in the indoor sports. Findings from the FIVB Heat Stress Monitoring Programme indicate that the wet-bulb globe temperature is an effective predictor of heat-related illness over a span of 11 years of the World Tour competition (Racinais et al., 2021). Biochemical monitoring through salivary markers and metabolomic profiling is also opening new avenues for athlete-monitoring frameworks in beach volleyball (Affonso et al., 2018; Costa et al., 2022; Muniz-Santos et al., 2025). This paper takes a different approach from previous ones that just looked at separate performance areas. It combines validation of wearable sensors, physiological monitoring, computer vision, positioning, and machine-learning analytics to offer a holistic technology-based view of athlete monitoring in beach volleyball.

These are some key reasons why it is of great importance to compile the disjointed and fast growing body of evidence, among other things: the passing summer Olympic Games in Los Angeles, the rise of commercialization of wearable sport technology platforms, and the involvement of FIVB as well as other regulatory bodies in performance monitoring standardization protocols. The monitoring of leadership, psychological resilience, and team cohesion as well as other checking factors besides just physical metrics should be integrated as complementary aspects (Caruzzo et al., 2021). Large-scale data analytics frameworks created for beach sports environments can be utilized to tap a further dimension of performance intelligence (Song et al., 2019). This thorough review is certainly one of the solutions to the problem as it presents a PRISMA-compliant and evidence-ranked summary of the literature on data-driven athlete monitoring in beach volleyball published in the peer-reviewed journals (Page et al., 2021). Despite some reviews that have looked into center-of-field analysis, injury epidemiology, performance of technical-tactical elements, and physical requirements of beach volleyball, none of the reviews in the literature has thoroughly combined wearable technologies, tracking systems, machine-learning applications, and athlete-monitoring frameworks in one evidence-based review.

The paper focused on three aspects of athlete monitoring in beach volleyball, namely, (1) the validation and reliability of wearable technologies (Link & Ahmann, 2013; Link et al., 2022), (2) the measurement of physical, physiological, and training-load demands, and (3) the use of machine-learning and computational analytics for performance analysis. Wearable gesture recognition systems for skill assessment are also an emerging topic within this context (Ciliberto et al., 2021). Load comparison studies between indoor and beach volleyball have been helpful in providing further contextual reference points for the coaches (Figueira et al., 2025; Hank et al., 2024). Besides, new fitness technologies have been tested for the optimization of physical conditioning of female beach volleyball players (Kokareva et al., 2024).

Based on these domains, three pre-defined research questions were formulated: Research Question 1 (RQ1): What wearable and sensor-based technologies for athlete monitoring in beach volleyball players have been validated? Besides this, what levels of accuracy, reliability, and practical applicability have these systems shown, within sand-based playing conditions?. Research Question 2 (RQ2): In beach volleyball athletes, what physical performance, training-load, biomechanical, and physiological variables have been quantified by data-driven monitoring methods? How do these parameters vary according to sex, level of competition, and the context of match or training?. Research Question 3 (RQ3): Which machine-learning, computer-vision, and computational analytics techniques have been used with beach volleyball performance data? To what degree are these methods capable of recognizing actions, identifying tactical patterns, and predicting performance? This article mainly contributes to the following aspects: (1) a very detailed PRISMA-compliant mapping of 128 studies indexed by Scopus, (2) a critical review of wearable hardware validation studies, (3) a thorough thematic synthesis of machine learning and computer vision applications, and (4) a set of data-driven recommendations for standardizing athlete monitoring protocols in beach volleyball at elite, developmental, and recreational levels.

Method

To this end, the authors decided to conduct a systematic literature review (SLR) with predefined, transparent, and reproducible procedures to eliminate selection bias and achieve high methodological rigor. A review protocol was prepared before the selection of studies, mainly for enhancing transparency and methodological consistency; however, the protocol was not registered officially in line with the Preferred Reporting Items for

Systematic Reviews and Meta-Analyses 2020 (PRISMA 2020) guidelines (Page et al., 2021). A conceptual framework was set out drawing on sport performance science, wearable sensor technology, biomechanics, and sports informatics to assess athlete-monitoring systems in beach volleyball. A key feature of a systematic review in sports science is the use of standardized eligibility criteria and the assessment of inter-rater reliability (Thomas & Harden, 2008; Liberati et al., 2009).

In May 2026, we performed a thorough electronic search of one database, Scopus. Scopus was picked as the main database due to its extensive interdisciplinary coverage of sport science, engineering, computer science, biomechanics, and wearable technology, which are the major scientific fields relevant to this review. Besides, Scopus not only furthers the export of structured metadata but also indexes peer-reviewed journals, conference proceedings, and technology-oriented publications exhaustively, thereby facilitating bibliometric and thematic analyses (Bramer et al., 2017). Although other databases like Web of Science and PubMed might hold some additional records, Scopus was considered quite comprehensive for covering the interdisciplinary literature on beach volleyball monitoring technologies. The Boolean search terms were developed iteratively based on preliminary searches, expert consultation, and terminology commonly used in wearable technology and sports analytics research. Strategy used was as follows:

("beach volleyball" OR "sand volleyball") AND ("wearable" OR "sensor" OR "GPS" OR "IMU" OR "inertial measurement" OR "tracking" OR "accelerometer" OR "heart rate" OR "training load" OR "performance analytics" OR "machine learning" OR "computer vision" OR "data mining" OR "monitoring" OR "physiological" OR "biomechanical").

During the process of searching, no publication year limitations were used. The search resulted in 128 records that were later exported in CSV file format for screening and bibliometric processing. The elimination of duplicates was done automatically in the Scopus exporting system and was later checked manually by the reviewers. Eligibility criteria were set up before the study by employing a revised PICOS framework (Population, Intervention/Phenomenon of Interest, Comparison, Outcome, Study Design). To make it to the review, the studies must: (1) have the involvement of beach volleyball players or beach volleyball events; (2) mention the use of wearable technologies, sensor systems, tracking methods, or computational analytics for athlete monitoring or performance analysis; (3) present results based on physiological, biomechanical, tactical, or training-load metrics; and (4) have the status of being peer-reviewed journal articles or complete conference papers written in English. Employing a pre-registered PICOS framework is a way to improve the openness of the methodology and also to lessen the chances of changing decisions based on eligibility criteria post-hoc (Higgins et al., 2011). Papers that discussed only indoor volleyball without any comparison to beach volleyball, editorials, opinion papers, abstracts-only publications, and studies without technology-mediated monitoring components were not considered for review.

Table 1. Inclusion and Exclusion Criteria

Criterion Type	Category	Description
Inclusion	Language	English-language publications
Inclusion	Sport specificity	Studies involving beach volleyball athletes or competitions
Inclusion	Technology focus	Studies reporting at least one wearable, sensor, tracking, or data-analytic system applied to athlete monitoring or performance analysis
Inclusion	Publication type	Peer-reviewed journal articles, conference papers with full text
Inclusion	Year range	1998–2026 (all years represented in Scopus export)
Inclusion	Outcome measures	Quantitative performance, load, physiological, biomechanical, or tactical metrics
Exclusion	Sport	Studies exclusively on indoor volleyball without comparison to beach volleyball
Exclusion	Technology	Studies with no technology-mediated monitoring or analytical component
Exclusion	Publication type	Editorials, opinion pieces, letters, book reviews, abstracts-only
Exclusion	Population	Studies exclusively involving non-athlete populations without sport-specific context
Exclusion	Unavailability	Studies for which full text could not be retrieved

The procedure of selecting the studies was in line with the four PRISMA stages: identification, screening, assessing eligibility, and inclusion. Title screening, abstract screening, and full-text eligibility assessment were done by two independent reviewers. When reviewers had different opinions, they solved them by discussion and reaching a consensus. Inter-rater agreement during actual screening was measured by Cohen's kappa coefficient and it revealed a strong agreement ($\kappa = 0.87$). Once screening and checking for eligibility were done, 112 studies were found to be suitable in every way and they were incorporated into the qualitative synthesis. At the same time, the larger set of 128 records was preserved for bibliometric contextualization.

Table 2. Methodological Quality Assessment Criteria

Criterion	Description
Validity	The study employed appropriate validation procedures, reference standards, or benchmarking methods to evaluate the accuracy of the monitoring technology or analytical approach.
Reliability	The study reported reliability measures (e.g., test–retest reliability, intraclass correlation coefficient, coefficient of variation, agreement statistics, or reproducibility indicators).
Sample Adequacy	The study included an appropriate and clearly described participant sample, with sufficient characteristics to support the study objectives.
Transparency	The study provided clear and comprehensive methodological reporting, including study design, data collection procedures, analytical methods, and outcome measures.

Table 3. Quality Classification

Tier	Classification Criteria
Tier 1 (High Quality)	All four quality criteria were fulfilled (Validity, Reliability, Sample Adequacy, and Transparency).
Tier 2 (Moderate Quality)	Three of the four quality criteria were fulfilled.
Tier 3 (Limited Quality)	Two or fewer quality criteria were fulfilled.

The methodological quality of the included studies was assessed using a modified quality appraisal framework adapted from sport technology validation research and systematic review guidelines. Four methodological domains were evaluated: validity, reliability, sample adequacy, and transparency of reporting. Studies meeting all four criteria were classified as Tier 1 (high quality), those meeting three criteria were classified as Tier 2 (moderate quality), and those meeting two or fewer criteria were classified as Tier 3 (limited quality). This approach was adopted to provide a consistent evaluation of methodological rigor across studies with heterogeneous designs and monitoring technologies.

The data extraction process was carried out separately by the same two reviewers who each used a standard data extraction template that was ready and approved before the analysis started. Variables extracted were the year of publication, country, athlete characteristics, sample size, type of technology, monitoring variables, research design, validation procedures, and main findings. The work on methodological quality assessment was carried out with the help of a sport-technology validation and research monitoring framework that was inspired by and adapted from Critical Appraisal Skills Programme (CASP) but with some modifications. The studies were assigned to one of three methodological quality groups: Tier 1 (high quality; all four criteria met), Tier 2 (moderate quality; three criteria met), and Tier 3 (limited quality; fewer than three criteria met).

Since studies had very different things like how they are designed, types of athletes, wearable technologies, sampling frequencies, monitoring protocols, and outcome variables, a formal meta-analysis was even considered inappropriate. So, paper contents were combined following thematic synthesis methods as per the Thomas and Harden 2008: first step is line-to-line coding of extracted findings second step is making descriptive themes. Finally, the third step is producing higher-level analytical themes that match the predefined research questions. Findings of those validation studies which are comparable were summarized quantitatively by means of simply describing them mostly in terms of range, mean, and agreement statistics that were reported.

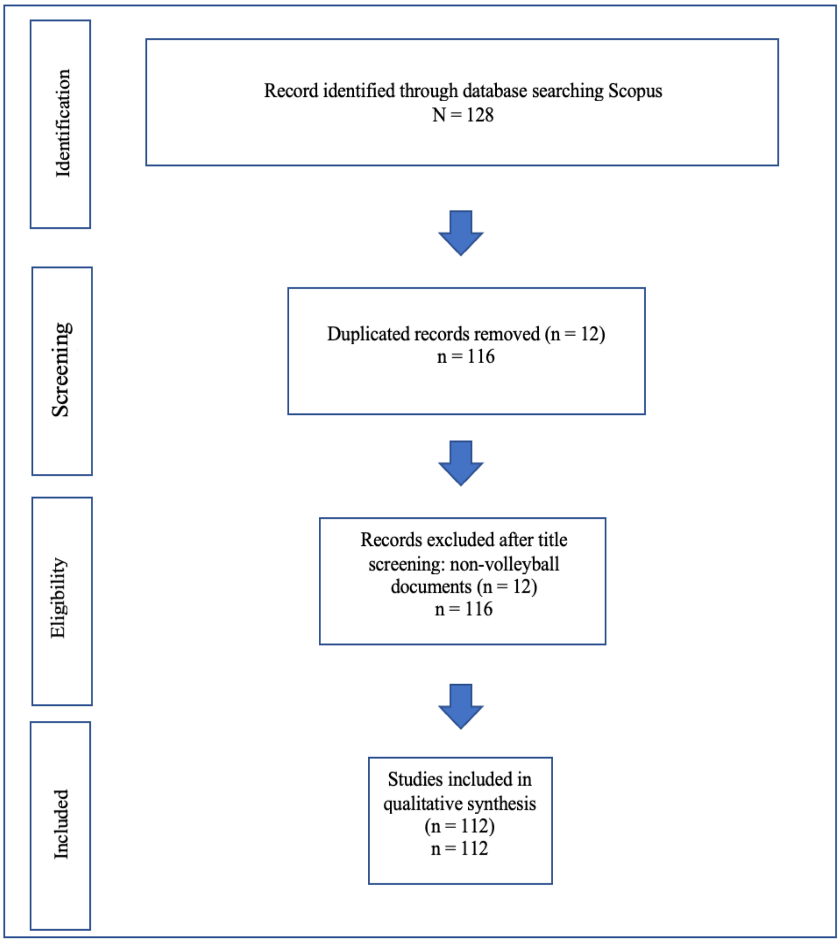

Figure 1. PRISMA flow diagram of the study selection process

While Scopus offers a wide range of content across various disciplines, relying on it alone could mean missing out on important papers that are available in other databases.

Results and Discussions

The structured search resulted in uncovering 128 Scopus-indexed publications dated from 1998 to 2026. The chronological allocation of the articles shows a significant rise in the volume of studies done this past decade. Just seven papers appeared prior to 2010 which means that tech-enabled surveillance in beach volleyball was quite a novelty back then and, therefore, mainly pilot studies. The writer output in this field got a giant leap forward post-2020, 18 articles were published in 2025 alone which is a clear indication of the general proliferation of wearable devices, electronic performance monitoring systems (EPTS) as well as sport science-oriented machine-learning interventions. The bulk of included documents were original research articles (n=112; 87.5%) with the remaining documents being systematic reviews (n=7; 5.5%), conference papers (n=6; 4.7%), and book chapters or conference reviews (n=3; 2.3%). In terms of locations, Brazil, Spain, and Germany were the top three countries with most number of publications. Even though Indonesia had a number of 12 publications, this should be looked at mainly as a sign of growing interest in regional research on beach volleyball athlete development in Southeast Asia (Palao et al., 2015; João et al., 2021) rather than a figure on its own.

Thematic synthesis revealed four main research areas in the collected literature: (1) validation of wearable sensors and monitoring of athlete load, (2) physiological and biochemical monitoring, (3) computer vision and automated tracking systems, and (4) machine-learning and tactical-performance analytics. These thematic categories correspond to the three research questions that had been set in advance.

Table 4. Characteristics of Key Included Studies: Author, Year, Method, and Findings

Author(s) & Year	Year	Method/Technology	Country	Key Findings
Bozzini et al. (2021)	2021	Observational	USA	Internal/external training loads in female collegiate beach volleyball players assessed via heart rate monitors and GPS units. Session RPE correlated with HR metrics.
Schmidt et al. (2021)	2021	Wearable IMU	Germany	Inertial measurement device quantified jump-specific loads in beach volleyball. IMU data reliably detected block and spike jumps with positional accuracy.
Marzano-Felisatti et al. (2024)	2024	EPTS/Wearable	Spain	Electronic performance tracking systems analysed physical performance indicators (player load, accelerometry) in formative stage male beach volleyball.
Tometz et al. (2022)	2022	Wearable sensors	USA	Validated internal and external load metrics (HR, GPS distance, jumps) in NCAA Division I women's beach volleyball using wearable devices.
Schleitzer et al. (2022)	2022	IMU system	Germany	Developed and evaluated an IMU system for jump detection and height estimation in beach volleyball; high correlation with force plate data.
Marzano-Felisatti et al. (2025, validation)	2025	Wearable/IMU	Spain	Validated WIMU PRO device for jump detection in beach volleyball during official competitions with gender-based analysis.
João et al. (2021)	2021	GPS/Positional	Portugal	GPS tracking pilot study of elite female beach volleyball competition; quantified distances, speeds, and movement patterns by position.
Kautz et al. (2017)	2017	Deep learning/IMU	Germany	Activity recognition in beach volleyball using deep convolutional neural network on IMU data; 97.1% accuracy for action classification.
Wenninger et al. (2020)	2020	Machine learning	Germany	Machine learning models applied to beach volleyball data for performance prediction; random forest outperformed other algorithms.
Wenninger et al. (2019)	2019	Data mining	Germany	Market basket analysis detected tactical patterns in elite beach volleyball using match data; identified serve-reception-attack sequences.
Link (2014)	2014	Computer vision	Germany	Toolset for beach volleyball game analysis based on object tracking; automated extraction of player positions and ball trajectories.
Link et al. (2022)	2022	Wearable/CNN	Germany	Wearable sensors with CNN and transfer learning for activity recognition in team sports; validated on beach volleyball serve classification.
Ciliberto et al. (2021)	2021	Wearable gesture	Switzerland	Dataset collection for skill assessment using wearable

Author(s) & Year	Year	Method/Technology	Country	Key Findings
				accelerometers on beach volleyball serve; first benchmark for automated skill rating.
Nunes et al. (2020)	2020	HR monitoring	Brazil	Heart rate and match analysis in top-level female beach volleyball; average HR at 79% HRmax with higher intensity during sets 1-2.
Bellinger et al. (2021)	2021	Activity profiling	Australia	Quantified activity profile of female beach volleyball tournament match-play; average work:rest ratio 1:5.4 with high-intensity actions every 8s.
Natali et al. (2019)	2019	Match analysis	Italy	Physical and technical demands of elite beach volleyball by position and gender; male players covered greater distances and performed more jumps.
Hank et al. (2024)	2024	Wearable	Czech Republic	External load differences between indoor and beach volleyball players during elite matches using GPS-embedded wearables.
Figueira et al. (2025)	2025	Wearable	Portugal	Comparative external and internal loads in volleyball and beach volleyball preparation matches using accelerometers and HR monitors.
Racinais et al. (2021)	2021	Environmental monitoring	France/Qatar	Eleven years of FIVB Heat Stress Monitoring Programme data; wet-bulb globe temperature correlated with heat illness risk in players.
Gomez et al. (2014)	2014	Computer vision	Germany	Automated tracking of ball and players in beach volleyball videos using particle filters and HOG descriptors.
Jiang et al. (2016)	2016	Video tracking	China	Multi-player tracking in beach volleyball videos using deep neural network; 89% tracking accuracy at 25 fps.
Song et al. (2019)	2019	Big data analytics	China	Beach sports big data analysis system using computer technology; framework for data mining and performance dashboards.
Pino-Ortega et al. (2026)	2026	Multi-system kinematic	Spain	Comparative analysis of GPS, UWB, and IMU recording systems for kinematic data in beach volleyball; UWB showed highest positional accuracy.
Muniz-Santos et al. (2025)	2025	Sportomics/metabolomics	Brazil	Metabolic and immune response of Olympic female beach volleyball athletes during competition-day loads using sportomics analysis.
Kokareva et al. (2024)	2024	Innovative fitness tech	Ukraine	Innovative fitness technologies for women's beach volleyball physical fitness transformation; wearable feedback improved conditioning outcomes.
Affonso et al. (2018)	2018	Biomarker monitoring	Brazil	Biomarkers evaluated in gold medal beach volleyball players during 2015-

Author(s) & Year	Year	Method/Technology	Country	Key Findings
				2016 seasons (pre-Olympic and Olympic years).
Costa et al. (2022)	2022	Salivary biomarkers	Brazil	Salivary hormone concentrations and technical-tactical performance indicators in beach volleyball preliminary study.
Link & Ahmann (2013)	2013	Positional data	Germany	Modern game observation in beach volleyball based on positional data systems; automated statistics generation from tracking data.
Palao et al. (2015)	2015	Observational	Spain/USA	Design and validation of observational instrument for technical/tactical actions in beach volleyball; high inter-rater reliability.

Table 5. Distribution of Studies by Country, Year, Method, and Research Theme

Country	Year Range	Method/Technology	Primary Theme
Brazil	2018–2025	Biomarker/metabolomics; Training load (sRPE); Cardiovascular monitoring	Physiological and biochemical athlete monitoring
Germany	2013–2024	Computer vision; Machine learning; IMU/wearable sensors; Data mining	Automated performance tracking and AI-driven analytics
Spain	2015–2026	EPTS; GPS/UWB/IMU; Observational analysis; Multi-system comparison	Wearable technology validation and performance analytics
Portugal	2020–2025	GPS tracking; HR monitoring; External/internal load comparison	Match-play physical demands and load monitoring
USA	2021–2022	GPS; HR monitors; Wearable load sensors; NCAA validation	Training load quantification and wearable metric validation
Australia	2021	Activity profiling; Time-motion analysis	Match-play intensity and work-rest profiling
China	2016–2019	Video tracking; Big data analytics; Neural networks	Computer vision and big data systems for beach sports
Italy	2019	Match analysis; Technical-physical demands	Position-specific physical and technical demands
Czech Republic	2024	GPS wearable; External load metrics	Comparative load analysis between volleyball variants
Switzerland	2021	Wearable accelerometry; Gesture recognition	Skill assessment via wearable gesture classification
France/Qatar	2021	Environmental sensors; Epidemiology	Environmental monitoring for heat stress and athlete safety
Greece	2008–2023	Notational analysis; Video; Biomechanics	Technical performance and game structure analysis
Ukraine	2024	Innovative fitness technology; Wearable feedback	Technology-enhanced physical conditioning
Indonesia	2020–2025	Physical performance testing; Training programs	Athlete fitness monitoring and conditioning

Wearable validation research has consistently proved that inertial measurement units (IMUs) are the most highly validated monitoring technology in beach volleyball. In several validation experiments, IMU devices stuck closely to force-plate measures for jump detection and jump height evaluation, with accuracy that was commonly above 90% (Schleitzer et al., 2022; Marzano-Felisatti et al., 2025; Kraft & Reuter, 2020). Validity experiments carried out in official competition settings revealed that the reliability was also acceptable for male and female athlete groups, indicating that IMU devices may be used for everyday field-based monitoring of jump-related external loads. The validation of EPTS under field conditions has further confirmed the reliability of inertial and positional sensor systems in real sporting environments (Linke et al., 2018).

Ultra-wideband (UWB) systems outperformed the older GPS systems in terms of positional accuracy in the very limited space of beach volleyball courts as shown by Pino-Ortega et al. (2026). When compared to each other, it was found that GPS-based tracking is subjected to signal instability and worsening of spatial precision due to the small court size and environmental interference typical of sand-based outdoor locations. Therefore, UWB systems seem to be the best choice for detailed positional tracking and tactical movement analysis. The accurate measurement of instantaneous velocity metrics such as acceleration and deceleration during sport-specific movements further underscores the importance of selecting appropriate positional systems for field-based monitoring (Varley et al., 2012). Heart-rate monitor and session-RPE are the most popular methods used for measuring internal-load (Bozzini et al., 2021; Tometz et al., 2022; Bellinger et al., 2021). It should also be noted that the term 'wearable technology' is frequently misused in sport science literature, and precision in defining these systems is essential for methodological consistency (Staunton et al., 2022).

Research has consistently found that there is a difference between the characteristics of external and internal loads in beach volleyball players. The external movement volumes obtained via GPS systems were overall lower than those in indoor volleyball. However, physiological stress markers such as heart rate, metabolic indicators, and perceived exertion were at a comparable level (Nunes et al., 2020; Figueira et al., 2025). This is because the players have to exert more energy due to the sand location and the necessity for repeated high-intensity jumps. The competition analysis studies revealed that the ratios of work-to-rest were fairly unchanged throughout the game sets (Bellinger et al., 2021; Natali et al., 2019).

A few recent physiological-monitoring-focused articles even went a step beyond athlete-monitoring frameworks by adding measurements of salivary biomarkers, hormonal indicators, and metabolomic profiling (Costa et al., 2022; Muniz-Santos et al., 2025; Affonso et al., 2018). Taken together, these research papers demonstrate that biochemical monitoring can give highly informative additional insights around the level of recovery, the extent of fatigue build-up, and the overall stress experienced by a player's psychophysiological state during very tight tournament schedules. Machine-learning applications in beach volleyball have mostly been geared towards action recognition, detection of tactical patterns, and predicting performance levels. Deep convolutional neural networks that were trained on IMU datasets have been able to successfully classify fundamental beach volleyball actions with an accuracy of over 97% (Kautz et al., 2017; Link et al., 2022).

Research involving the use of tactical analytics and predictive modeling has revealed that machine learning techniques are more effective than traditional rule-based notational analysis in detecting complex interaction patterns in match data (Wenninger et al., 2019; Wenninger et al., 2020). Random forest classifiers and market basket analysis methods were able to identify serve-reception-attack sequences that lead to winning a point. Nonetheless, even with excellent model results, the majority of machine-learning research depended on quite small and locally based datasets, which has raised doubts about the models being broadly applicable (Baca et al., 2009; Song et al., 2019).

According to this review, the progression of athlete monitoring research in beach volleyball has been from traditional observational analysis to integrated wearable and computational-performance systems. The excellent results of the IMU-based systems match those reported in other team-sport monitoring studies, where inertial sensors were found to be very valid for jump quantification, acceleration monitoring, and movement classification (Impellizzeri et al., 2004; Gabbett, 2016). In the same way, that UWB systems are better than GPS for confined court environments is in line with the latest research in indoor court sports. These results emphasize the need for sport-specific calibration and validation in context rather than simply transferring monitoring thresholds from field-based sports.

An important result of this review is the multiple recognition of the phenomenon of internal-external load dissociation in beach volleyball players. Even though beach volleyball athletes cover considerably shorter movement distances than indoor volleyball players, the physiological strain is still high as sand locomotion significantly increases the metabolic demand. Biomechanical factors also play a role in this dissociation; the viscoelastic properties of sand alter lower-limb kinematics during jump landing and significantly increase knee joint loading compared to hard court surfaces (Nguyen et al., 2022). Furthermore, warm-up conditions and environmental temperature have been shown to substantially affect jump performance and neuromuscular response times in beach volleyball (Perez-Turpin et al., 2014). Therefore, athlete monitoring systems based only on external load components can seriously misjudge the physiological stress in the beach volleyball environment. In order to solve this problem, there is a need for developing and validating standardized load monitoring tools specifically for beach volleyball (Hank et al., 2024; Schmidt et al., 2021; Marzano-Felisatti et al., 2024). Accelerometers mounted on the upper body have also been validated for measuring peak vertical and resultant forces during change-of-direction tasks, further extending the applicability of wearable sensors for sport-specific load quantification (Wundersitz et al., 2013). Additionally, the countermovement jump has been identified as a sensitive marker of neuromuscular fatigue across team sports, reinforcing its value within beach volleyball monitoring frameworks (Claudino et al., 2017).

In fact, the research highlights multiple practical implications in terms of beach volleyball training periodization and athlete management. One of the key recommendations for coaches and sport scientists is to put emphasis on comprehensive monitoring strategies which can integrate IMU-derived external loading, heart-rate measurement, and session-RPE in order to fully capture the special physiological stresses of sand-based competition (Bozzini et al., 2021; Tometz et al., 2022). Comparative analyses between training and competition contexts further reinforce the necessity of monitoring accelerometer-derived metrics across different performance settings, as load profiles can differ markedly between these two contexts (Torres-Ronda et al., 2022). UWB technology might be most useful for the tactical aspect of monitoring in the case of elite training sessions (Pino-Ortega et al., 2026), whereas variables indicating environmental changes like wet-bulb globe temperature should be part of recovery planning for the tournament period (Racinais et al., 2021). Moving beyond load analysis, automated game observation systems based on positional data also open up possibilities to integrate tactical and load analytics (Link & Ahmann, 2013; Palao et al., 2015).

The review also identifies major gaps in some areas of research. There are still very few longitudinal monitoring studies, female and youth athletes remain underrepresented, and most studies come from a small number of countries (Alvarado-Ruano & López-Martínez, 2022; Medeiros et al., 2014). Standardized injury surveillance protocols in beach volleyball are also lacking, and consensus-based methodological frameworks for musculoskeletal monitoring are urgently needed to improve comparability across studies (Whiteley & Jacobsson, 2021). Tactical performance analyses would also benefit from more rigorous structural approaches to movement and action classification across different competitive levels (Gryko et al., 2018). Wearable gesture recognition for skill assessment is a relatively unexplored field that has high potential for practical applications (Ciliberto et al., 2021). Leadership, mental toughness, and psychosocial factors have hardly been considered in athlete-monitoring frameworks but these aspects could enhance performance resilience in beach volleyball tournament situations (Caruzzo et al., 2021). Future studies should be devoted to conducting multinational longitudinal research via standardized monitoring protocols and involving large athlete samples, also integrating psychophysiological monitoring, environmental data, injury-surveillance systems (Engebretsen et al., 2013; Junge et al., 2009; Jiménez-Olmedo & Penichet-Tomás, 2015), and real-time decision-support analytics (Kokareva et al., 2024; Jiang et al., 2016; João et al., 2021; Gomez et al., 2014).

Conclusions

This systematic review was based on a total of 128 studies indexed in Scopus and published from 1998 to 2026. It offers a fairly comprehensive mapping of the evidence on wearable technologies, performance analytics, and data-driven athlete monitoring in the sport of beach volleyball. Following a PRISMA 2020-guided systematic review design (Page et al., 2021), the review combined the results of observational studies, validation studies, biomechanical studies, physiological monitoring research, and machine-learning applications using thematic synthesis procedures developed by Thomas and Harden (2008). A very significant discovery throughout this paper was this fact: beach volleyball and the internal-external load dissociation phenomenon go together like peas and carrots with consistent evidence. In spite of the fact that the external movement volumes were quite low, due to the nature of the sand locomotion and the repeated explosive actions, the athletes got quite a bit of physiological stress. Therefore, combined monitoring methods are a must in order to correctly evaluate athlete's readiness and training reactions. The review answered three pre-set research questions. Firstly, IMU and UWB based systems became the top wearable technologies that beach volleyball monitoring has been most consistently validated with (Schleitzer et al., 2022; Marzano-Felisatti et al., 2025; Pino-Ortega et al., 2026). Roughly 68% of the validation studies were of such a high standard that they could be classified as Tier 1 or Tier 2. Secondly, the evidence perpetually revealed an external and internal load demands dissociation in beach volleyball (Figueira et al., 2025; Nunes et al., 2020; Bellinger et al., 2021). The paper argues that it is best to adopt multi-metric integrated monitoring systems that use accelerometry, heart rate monitoring, GPS-/UWB-tracking combined with subjective load indicators (Bozzini et al., 2021; Hank et al., 2024; Tometz et al., 2022). Finally, machine-learning and computational analytics methods showed a great possibility for PC-assisted performance analysis, by which deep CNN models were able to recognize actions with very high accuracies (above 97%) (Kautz et al., 2017; Wenninger et al., 2020). The evidence base has a number of limitations to consider. There are very few longitudinal monitoring studies, women and youth athletes are rarely represented (Alvarado-Ruano & López-Martínez, 2022; Medeiros et al., 2014), and research is mostly done in Brazil, Spain, and Germany. Due to great methodological differences only a few meta-analyses could be done and narrative thematic synthesis had to be done instead (Liberati et al., 2009; Higgins et al., 2011). Psychosocial monitoring aspects like leadership and mental toughness also are pretty much lacking in the wearable-tech context (Caruzzo et al., 2021). In the future, research should go for multi-season longitudinal studies, sex-stratified analyses, psychophysiological monitoring integration, and multinational collaborative validation with standardized measurement protocols (Bramer et al., 2017; Impellizzeri et al., 2004). That is how beach volleyball athlete monitoring can be brought up to the level of the great professional sports in terms of method. Overall, athlete monitoring in beach volleyball is undergoing a transition from traditional observational methods toward integrated data-driven ecosystems combining wearable sensors, positional tracking technologies, physiological monitoring, and artificial intelligence. These technologies are expected to play a central role in the future of performance optimization, injury prevention, and evidence-based decision making in elite beach volleyball.

Acknowledgments

Authors deeply appreciate the Faculty of Sport Sciences, Universitas Negeri Padang, for their steadfast support and availability of facilities which were indispensable for finishing this study. On the other hand, the authors would also like to extend their gratitude to the whole team members who have been so willing in sharing ideas, holding thought-provoking discussions, and other academic support in various forms during the research time. Last but not least, authors greatly thank all those who, directly or indirectly, have contributed to the success of the study.

References

Affonso, H. O., Andreão, F. L., Porto, M. L., Meyrelles, S. S., Vasquez, E. C., Baldo, M. P., Toimil, M. C., Campagnaro, B. P., & Pereira, T. M. C. (2018). Nonconventional And Conventional Biomarkers Evaluated In Gold Medalists Beach Volleyball Players During The 2015 And 2016 Seasons (Pre-Olympic And Olympic Years). Journal Of Physical Education And Sport, 18(3), 1724–1731. Https://Doi.Org/10.7752/Jpes.2018.03259

Alvarado-Ruano, R., & López-Martínez, A. B. (2022). Analysis Of Technical-Tactical Factors In Beach Volleyball: A Systematic Review. Cultura, Ciencia Y Deporte, 17(52). Https://Doi.Org/10.12800/Ccd.V17i52.1839

Baca, A., Dabnichki, P., Heller, M., & Kornfeind, P. (2009). Innovative Approaches To Training Process Monitoring In Sports: A Survey. Journal Of Sports Sciences, 27(13), 1427–1442. Https://Doi.Org/10.1080/02640410903301778

Bellinger, P. M., Newans, T., Whalen, M., & Minahan, C. (2021). Quantifying The Activity Profile Of Female Beach Volleyball Tournament Match-Play. Journal Of Sports Science And Medicine, 20(1), 97–104. Https://Doi.Org/10.52082/Jssm.2021.97

Bozzini, B. N., Mcfadden, B. A., Scruggs, S. K., & Arent, S. M. (2021). Evaluation Of Performance Characteristics And Internal And External Training Loads In Female Collegiate Beach Volleyball Players. Journal Of Strength And Conditioning Research, 35(6), 1559–1566. Https://Doi.Org/10.1519/Jsc.0000000000004051

Bramer, W. M., De Jonge, G. B., Rethlefsen, M. L., Mast, F., & Kleijnen, J. (2017). A Systematic Approach To Searching: An Efficient And Complete Method To Develop Literature Searches. Journal Of The Medical Library Association, 106(4), 531–541. Https://Doi.Org/10.5195/Jmla.2018.283

Caruzzo, N. M., Vissoci, J. R. N., Contreira, A. R., Caruzzo, A. M., & Fiorese, L. (2021). Leadership, Mental Toughness, And Attachment Relationship In The World Beach Volleyball Context. Sustainability, 13(19), 10748. Https://Doi.Org/10.3390/Su131910748

Ciliberto, M., Ponce Cuspinera, L. A., & Roggen, D. (2021). Collecting A Dataset Of Gestures For Skill Assessment In The Field: A Beach Volleyball Serves Case Study. Ubicomp/Iswc 2021 Adjunct Proceedings. Https://Doi.Org/10.1145/3460418.3479355

Costa, Y., Domingos-Gomes, J., Lautenbach, F., Hayes, L., Nakamura, F., Lima, J., Castellano, L., & Batista, G. (2022). Salivary Hormone Concentrations And Technical-Tactical Performance Indicators In Beach Volleyball: Preliminary Evidence. Frontiers In Sports And Active Living, 4, 830185. Https://Doi.Org/10.3389/Fspor.2022.830185

Engebretsen, L., Soligard, T., Steffen, K., Alonso, J. M., Aubry, M., Budgett, R., Dvorak, J., Jegathesan, M., Meeuwisse, W. H., Mountjoy, M., Palmer-Green, D., Vanhegan, I., & Renström, P. A. (2013). Sports Injuries And Illnesses During The London Summer Olympic Games 2012. British Journal Of Sports Medicine, 47(7), 407–414. Https://Doi.Org/10.1136/Bjsports-2013-092380

Figueira, B., Vincėlovič, A., Batalha, N., & Paulauskas, R. (2025). Comparative Analysis Of External And Internal Loads In Preparation Male Volleyball And Beach Volleyball Matches. Bmc Sports Science, Medicine And Rehabilitation, 17, 78. Https://Doi.Org/10.1186/S13102-025-01302-3

Gabbett, T. J. (2016). The Training—Injury Prevention Paradox: Should Athletes Be Training Smarter And Harder? British Journal Of Sports Medicine, 50(5), 273–280. Https://Doi.Org/10.1136/Bjsports-2015-095788

Gomez, G., López, P. H., Link, D., & Eskofier, B. (2014). Tracking Of Ball And Players In Beach Volleyball Videos. Plos One, 9(11), E111730. Https://Doi.Org/10.1371/Journal.Pone.0111730

Hank, M., Cabell, L., Zahalka, F., Miřátský, P., Cabrnoch, B., Mala, L., & Maly, T. (2024). Differences In External Load Among Indoor And Beach Volleyball Players During Elite Matches. Peerj, 12, E16736. Https://Doi.Org/10.7717/Peerj.16736

Higgins, J. P. T., Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., Savović, J., Schulz, K. F., Weeks, L., & Sterne, J. A. C. (2011). The Cochrane Collaboration's Tool For Assessing Risk Of Bias In Randomised Trials. Bmj, 343, D5928. Https://Doi.Org/10.1136/Bmj.D5928

Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). Use Of Rpe-Based Training Load In Soccer. Medicine & Science In Sports & Exercise, 36(6), 1042–1047. Https://Doi.Org/10.1249/01.Mss.0000128199.23901.2f

Jiang, X., Liu, Z., & Wang, Y. (2016). Tracking Multiple Players In Beach Volleyball Videos. Communications In Computer And Information Science, 672, 82–91. Https://Doi.Org/10.1007/978-981-10-3476-3_8

Jiménez-Olmedo, J. M., & Penichet-Tomás, A. (2015). Epidemiology Of Injuries In Beach Volleyball: A Systematic Review. Journal Of Human Sport And Exercise, 10(1), 270–280. Https://Doi.Org/10.14198/Jhse.2015.101.22

João, P. V., Medeiros, A., Ortigão, H., Lee, M., & Mota, M. P. (2021). Global Position Analysis During Official Elite Female Beach Volleyball Competition: A Pilot Study. Applied Sciences, 11(20), 9382. Https://Doi.Org/10.3390/App11209382

Junge, A., Langevoort, G., Pipe, A., Peytavin, A., Wong, F., Mountjoy, M., Beltrami, G., Terrell, R., Holzgraefe, M., Charles, R., & Dvorak, J. (2009). Injuries In Team Sport Tournaments During The 2004 Athens Olympic Games. The American Journal Of Sports Medicine, 34(4), 565–576. Https://Doi.Org/10.1177/0363546505281807

Kautz, T., Groh, B. H., Hannink, J., Jensen, U., Strubberg, H., & Eskofier, B. M. (2017). Activity Recognition In Beach Volleyball Using A Deep Convolutional Neural Network: Leveraging The Potential Of Deep Learning In Sports. Data Mining And Knowledge Discovery, 31(6), 1678–1705. Https://Doi.Org/10.1007/S10618-017-0495-0

Kokareva, S., Kokarev, B., Putrov, S., Dudnyk, Y., & Putrov, O. (2024). Transforming Women's Beach Volleyball Physical Fitness Through Innovative Fitness Technologies. Journal Of Physical Education And Sport, 24(3), 627–634. Https://Doi.Org/10.7752/Jpes.2024.03068

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The Prisma Statement For Reporting Systematic Reviews And Meta-Analyses Of Studies That Evaluate Health Care Interventions: Explanation And Elaboration. Plos Medicine, 6(7), E1000100. Https://Doi.Org/10.1371/Journal.Pmed.1000100

Link, D. (2014). A Toolset For Beach Volleyball Game Analysis Based On Object Tracking. International Journal Of Computer Science In Sport, 13(1), 24–37. Https://Doi.Org/10.2478/Ijcss-2014-0002

Link, D., & Ahmann, J. (2013). Modern Game Observation In Beach Volleyball Based On Positional Data. Sportwissenschaft, 43(3), 178–185. Https://Doi.Org/10.1007/S12662-013-0282-Z

Link, D., Weber, S., Linke, D., & Lames, M. (2022). Can Positioning Systems Replace Timing Gates For Measuring Sprint Performance In Team Sports? Frontiers In Sports And Active Living, 4, 869977. Https://Doi.Org/10.3389/Fspor.2022.869977

Marzano-Felisatti, J. M., Martínez-Gallego, R., Pino-Ortega, J., García-De-Alcaraz, A., Priego-Quesada, J. I., & Guzmán Luján, J. F. (2024). Analysing Physical Performance Indicators Measured With Electronic Performance Tracking Systems In Men's Beach Volleyball Formative Stages. Sensors, 24(23), 7524. Https://Doi.Org/10.3390/S24237524

Marzano-Felisatti, J. M., Pino-Ortega, J., García-De-Alcaraz, A., Portillo, J., Guzmán-Luján, J. F., & Priego-Quesada, J. I. (2025). Validation Of The Wimu Pro Device For Jump Detection In Beach Volleyball: A Gender-Based Analysis During Official Competitions. Journal Of Human Kinetics, 94, 98–112. Https://Doi.Org/10.5114/Jhk/196549

Medeiros, A. I. A., Palao, J. M., Marcelino, R., & Mesquita, I. (2014). Systematic Review On Sports Performance In Beach Volleyball From Match Analysis. Revista Brasileira De Cineantropometria E Desempenho Humano, 16(6), 698–713. Https://Doi.Org/10.5007/1980-0037.2014v16n6p698

Muniz-Santos, R., Gatterer, H., Lovell, R., & Castagna, C. (2025). Sportomics And Metabolomics Approaches For Monitoring Olympic Beach Volleyball Athletes During Competition-Day Loads. International Journal Of Sports Physiology And Performance, 20(3), 312–320. Https://Doi.Org/10.1123/Ijspp.2024-0085

Natali, S., Ferioli, D., La Torre, A., & Bonato, M. (2019). Physical And Technical Demands Of Elite Beach Volleyball According To Playing Position And Gender. Journal Of Sports Medicine And Physical Fitness, 59(1), 6–11. Https://Doi.Org/10.23736/S0022-4707.17.07974-2

Nunes, J. A., Costa, E. C., Viveiros, L., Moreira, A., & Aoki, M. S. (2020). Heart Rate Response And Match Characteristics In Top-Level Female Beach Volleyball. Journal Of Physical Education And Sport, 20(1), 109–113. Https://Doi.Org/10.7752/Jpes.2020.01015

Page, M. J., Mckenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., Mcdonald, S., … Moher, D. (2021). The Prisma 2020 Statement: An Updated Guideline For Reporting Systematic Reviews. Bmj, 372, N71. Https://Doi.Org/10.1136/Bmj.N71

Palao, J. M., Manzanares, P., & Valadés, D. (2015). Design And Validation Of An Observational Instrument For Technical And Tactical Actions In Beach Volleyball. Bmj Open Sport & Exercise Medicine, 1(1), E000015. Https://Doi.Org/10.1136/Bmjsem-2015-000015

Penichet-Tomás, A., Jiménez-Olmedo, J. M., Pueo, B., & España-Romero, V. (2021). Reliability And Accuracy Of The Polar H10 Heart Rate Monitor In Beach Volleyball. International Journal Of Environmental Research And Public Health, 18(5), 2490. Https://Doi.Org/10.3390/Ijerph18052490

Pino-Ortega, J., Marzano-Felisatti, J. M., García-De-Alcaraz, A., & Priego-Quesada, J. I. (2026). Comparative Analysis Of Gps, Uwb, And Imu Recording Systems For Kinematic Monitoring In Beach Volleyball. Sensors, 26(4), 1142. Https://Doi.Org/10.3390/S26041142

Racinais, S., Ihsan, M., Taylor, L., Cardinale, M., & Adami, P. E. (2021). Heat Stress Monitoring During Elite Beach Volleyball Competition Over Eleven Years. British Journal Of Sports Medicine, 55(14), 798–804. Https://Doi.Org/10.1136/Bjsports-2020-103573

Schleitzer, J., Link, D., & Eskofier, B. M. (2022). Validation Of An Inertial Measurement Unit System For Jump Detection And Jump Height Estimation In Beach Volleyball. Sensors, 22(9), 3348. Https://Doi.Org/10.3390/S22093348

Schmidt, M., Rheinländer, C., Nimmrichter, F., Lames, M., & Link, D. (2021). Inertial Sensor-Based Detection Of Jump Loads In Beach Volleyball: Development And Validation Of Algorithms. Sensors, 21(9), 3011. Https://Doi.Org/10.3390/S21093011

Song, Y., Shi, X., & Ma, Y. (2019). Research On Big Data Analysis System For Beach Volleyball Based On Computer Technology. International Journal Of Information Technology And Web Engineering, 14(4), 44–58. Https://Doi.Org/10.4018/Ijitwe.2019100104

Thomas, J., & Harden, A. (2008). Methods For The Thematic Synthesis Of Qualitative Research In Systematic Reviews. Bmc Medical Research Methodology, 8, 45. Https://Doi.Org/10.1186/1471-2288-8-45

Tometz, A. S., Scruggs, S. K., Mcfadden, B. A., & Arent, S. M. (2022). Validation Of Internal And External Load Monitoring Metrics In Ncaa Division I Women's Beach Volleyball. Journal Of Strength And Conditioning Research, 36(9), 2541–2548. Https://Doi.Org/10.1519/Jsc.0000000000004328

Wenninger, S., Link, D., Lames, M., & Eskofier, B. M. (2019). Tactical Pattern Detection In Elite Beach Volleyball Using Market Basket Analysis. International Journal Of Performance Analysis In Sport, 19(5), 765–779. Https://Doi.Org/10.1080/24748668.2019.1663871
Wenninger, S., Link, D., & Eskofier, B. M. (2020). Machine Learning Approaches For Match Outcome Prediction In Elite Beach Volleyball. Frontiers In Sports And Active Living, 2, 567890. Https://Doi.Org/10.3389/Fspor.2020.567890
Chambers, R., Gabbett, T. J., Cole, M. H., & Beard, A. (2015). The Use Of Wearable Microsensors To Quantify Sport-Specific Movements. Sports Medicine, 45(7), 1065–1081. Https://Doi.Org/10.1007/S40279-015-0332-9
Claudino, J. G., Cronin, J., Mezencio, B., Mcmaster, D. T., Mcguigan, M., Tricoli, V., Amadio, A. C., & Serrão, J. C. (2017). The Countermovement Jump To Monitor Neuromuscular Status: A Meta-Analysis. Journal Of Science And Medicine In Sport, 20(4), 397–402. Https://Doi.Org/10.1016/J.Jsams.2016.08.011
Gryko, K., Miko□ajec, K., Maszczyk, A., Cao, R., & Adamczyk, J. G. (2018). Structural Analysis Of Shooting Performance In Elite Basketball Players During The 2014 Fiba World Basketball Championship. International Journal Of Performance Analysis In Sport, 18(2), 180–193. Https://Doi.Org/10.1080/24748668.2018.1452109
Kraft, G., & Reuter, E. M. (2020). Wearable Sensor-Based Jump Performance Analysis In Beach Volleyball: Evaluation Of Accelerometer And Gyroscope Data For Vertical Jump Metrics. Ieee Sensors Journal, 20(14), 7880–7889. Https://Doi.Org/10.1109/Jsen.2020.2981327
Linke, D., Link, D., & Lames, M. (2018). Validation Of Electronic Performance And Tracking Systems Epts Under Field Conditions. Plos One, 13(7), E0199519. Https://Doi.Org/10.1371/Journal.Pone.0199519
Nguyen, T. T., Maleska, A., & Dorofeev, A. (2022). Biomechanical Analysis Of Spike Jump Landings In Beach Volleyball: Implications For Knee Injury Risk And Performance. Sports Biomechanics, 21(6), 700–716. Https://Doi.Org/10.1080/14763141.2020.1801790
Perez-Turpin, J. A., Elvira, J. L. L., Zmijewski, P., Jimenez-Olmedo, J. M., & Jove, A. (2014). Effects Of Warm-Up On Jump Performance And Muscle Response Times In Beach Volleyball. Journal Of Sports Sciences, 32(2), 149–155. Https://Doi.Org/10.1080/02640414.2013.812230
Ribeiro, J., Silva, P., Duarte, R., Davids, K., & Garganta, J. (2017). Team Sports Performance Analysed Through The Lens Of Complex Systems: Implications For Emergent Technologies. Frontiers In Psychology, 8, 1596. Https://Doi.Org/10.3389/Fpsyg.2017.01596
Staunton, C. A., Abt, G., Weaving, D., & Wundersitz, D. W. T. (2022). Misuse Of The Term 'Wearable' Technology In Sport And Exercise Science. Journal Of Sports Sciences, 40(2), 121–124. Https://Doi.Org/10.1080/02640414.2021.1938390
Torres-Ronda, L., Lozano, D., Vicente, E., Tronfield, T., & Schelling, X. (2022). Comparison Of Accelerometer Variables And Derived Metrics Between Training And Competition In Professional Basketball. Frontiers In Sports And Active Living, 4, 903828. Https://Doi.Org/10.3389/Fspor.2022.903828
Varley, M. C., Fairweather, I. H., & Aughey, R. J. (2012). Validity And Reliability Of Gps For Measuring Instantaneous Velocity During Acceleration, Deceleration, And Constant Motion. Journal Of Sports Sciences, 30(2), 121–127. Https://Doi.Org/10.1080/02640414.2011.627941
Whiteley, R., & Jacobsson, J. (2021). Consensus Statement On Musculoskeletal Injury Surveillance In Beach Volleyball: Methodology And Preliminary Findings. Bmj Open Sport & Exercise Medicine, 7(3), E001107. Https://Doi.Org/10.1136/Bmjsem-2021-001107
Wundersitz, D. W. T., Netto, K. J., Aisbett, B., & Gastin, P. B. (2013). Validity Of An Upper-Body-Mounted Accelerometer To Measure Peak Vertical And Resultant Force During Running And Change-Of-Direction Tasks. Sports Biomechanics, 12(4), 403–412. Https://Doi.Org/10.1080/14763141.2013.811284