Стаття поширюється на умовах ліцензії CC BY 4.0

USING IT IN VOLLEYBALL CLASSES TO IMPLEMENT DIFFERENTIATED METHODS IMPROVEMENT OF PHYSICAL TRAINING OF PLAYERS

Vlasenko A.

*Postgraduate Student at the Department of the Theories and Methods
of Physical Culture
Sumy State Pedagogical University named after A. S. Makarenko
Romenska str., 87, Sumy, Ukraine
orcid.org/0009-0003-0530-2956
antonio03121993vl@gmail.com*

Information technologies penetrate into all aspects of the training process, from analyzing players' movements to developing tactical strategies and modeling game situations. Therefore, the use of modern IT in volleyball classes to implement differentiated methods of improving the physical fitness of female students is an interesting and urgent problem that requires a comprehensive analysis of possible IT solutions. The purpose of the study is to characterize the technologies that can be used in volleyball classes to implement differentiated methods of improving players' physical fitness. The study used a comparative analysis of approaches to IT use in volleyball, presented in scientific publications, and a content analysis of Internet resources that describe digital tools used by athletes and coaches to support volleyball training today. Implementing such tools as video analysis, biomechanical sensors, artificial intelligence, virtual reality, and machine learning is described. It is confirmed that their use allows to record indicators and adapt the load, technique, and training strategy to a particular athlete. Video analysis makes it possible to study a player's movement technique in detail, compare it with reference samples, and identify errors that may not be noticeable during standard training, which can form the basis for developing individual corrective exercises to eliminate weaknesses. Motion sensors and biomechanical analysis objectively assess physical performance, such as reaction time, jumping power, or kicking accuracy. This data allows us to determine each player's training level and form groups with similar needs. Artificial intelligence and machine learning enable automating the analysis of large data sets, predicting the effectiveness of various training programs, and offering optimal solutions for each player. Virtual reality technologies create simulated game situations where players can practice specific skills in a controlled environment. It has been proven that using such technologies is especially useful for differentiating training.

ВИКОРИСТАННЯ ІТ НА ЗАНЯТТЯХ ІЗ ВОЛЕЙБОЛУ ДЛЯ РЕАЛІЗАЦІЇ ДИФЕРЕНЦІЙОВАНИХ МЕТОДИК УДОСКОНАЛЕННЯ ФІЗИЧНОЇ ПІДГОТОВКИ ГРАВЦІВ

Власенко А.
аспірант кафедри теорії та методики фізичної культури
Сумський державний педагогічний університет імені А. С. Макаренка
вул. Роменська, 87, Суми, Україна
orcid.org/0009-0003-0530-2956
antonio03121993vl@gmail.com

Ключові слова: *волейбол, диференційовані методики, ІТ, фізична підготовка, удосконалення, спорт.*

Інформаційні технології проникають у всі аспекти тренувального процесу – від аналізу рухів гравців до розроблення тактичних стратегій та моделювання ігрових ситуацій. Тому використання сучасних ІТ на заняттях із волейболу для реалізації диференційованих методик удосконалення фізичної підготовки студенток є цікавою і водночас актуальною проблемою, для вирішення якої потрібен усебічний аналіз можливих ІТ-рішень. Метою дослідження є характеристика технологій, які можна використовувати на заняттях із волейболу для реалізації диференційованих методик удосконалення фізичної підготовки гравців. Методом дослідження став компаративний аналіз підходів до використання ІТ у волейболі, який представлений у наукових публікаціях, та контент-аналіз Інтернет-ресурсів, які описують цифрові інструменти, що використовуються спортсменами й тренерами для супроводу занять волейболом сьогодні. Описано впровадження таких інструментів, як відеоаналіз, біомеханічні датчики, штучний інтелект, віртуальна реальність і машинне навчання. Підтверджено, що їх використання дає змогу не лише фіксувати показники, а й адаптувати навантаження, техніку та стратегію тренувань під конкретного спортсмена. Відеоаналіз дає змогу детально вивчати техніку рухів гравця, порівнювати її з еталонними зразками та виявляти помилки, які можуть бути непомітними під час стандартного тренування, що може стати основою для розроблення індивідуальних корекційних вправ, спрямованих на усунення слабких місць. Датчики руху та біомеханічний аналіз забезпечують об'єктивну оцінку фізичних показників, таких як швидкість реакції, сила стрибка або точність удару. Ці дані дають змогу визначати рівень підготовки кожного гравця та формувати групи з подібними потребами. Штучний інтелект і машинне навчання дають змогу автоматизувати аналіз великих масивів даних, прогнозувати ефективність різних тренувальних програм та пропонувати оптимальні рішення для кожного гравця. Технології віртуальної реальності створюють імітацію ігрових ситуацій, де гравець може відпрацьовувати конкретні навички в контрольованому середовищі. Доведено, що використання таких технологій особливо корисне для диференціації тренувань.

Problem statement. The conditions of the modern educational process require individualization of training, taking into account the level of physical fitness, health, and motivation of each student. However, traditional approaches often do not allow for complete adaptation of the training process to the needs of individual groups. This is where modern IT solutions can come: from mobile applications and virtual coaches to motion analysis systems and Big Data for monitoring sports results. Modern sports, including volleyball, are being significantly influenced by technological progress not only at the professional level but also at the local level. Information technology penetrates all aspects of the training process, from analyzing player movements to developing tactical strategies and modeling game situations. Therefore, the use of modern IT in volleyball classes to implement differentiated methods of improving the physical fitness of female students is an interesting and urgent problem that requires a comprehensive analysis of possible IT solutions.

Analysis of current research. Recently, we have noted many studies in which researchers have addressed the problem of using IT in sports to monitor physical condition, optimize the training process, and prevent injuries to people engaged in physical activity. Among these are real-time physical performance monitoring technologies that allow collecting data on heart rate, step frequency, fatigue level, and muscle load [15].

Cameras and computer vision systems allow you to record the technique of performing exercises, assess the correctness of movements, and prevent errors [10].

A separate aspect of the use of IT in sports is the personalization of training programs. Today, IT allows the creation of individualized training plans based on a person's physical data, such as endurance, strength, and flexibility. This ensures that the load is adapted to their needs and goals. In particular, platforms like Athletica (https://athletica.ai) use machine learning to adjust programs in real time depending on the progress or fatigue of users.

Today, IT in sports is also associated with injury prevention. For example, an abnormally high heart rate or improper technique can warn of the need to reduce training intensity. Injury prediction is based on the analysis of biomechanical parameters and loads. It allows you to avoid overloads and minimize the risk of injury [15]. Technologies help to track changes in users' physical condition over a long period by analyzing data on their endurance, strength, and other parameters. This helps to form healthy habits and optimize training plans.

Digital health tools should be mentioned separately. Wearable devices, such as fitness trackers, smartwatches, and specialized sensors, allow the collection of various information about users' physical activity [2]. These devices can measure heart rate, number of jumps, distance traveled, speed of movement, and other vital indicators [13]. The sensors can also record physiological indicators (heart rate, fatigue) and jumping parameters. In particular, it is possible to track jumping loads using mobile devices [4]. Such data can be used to personalize training programs and detect signs of fatigue promptly. Learning to use them is already evident in some training programs for physical education and sports specialists [9].

Thus, the analysis of scientific publications of recent years shows the active use of IT in sports. At the same time, the generalization of the results shows the lack of research on the use of IT in volleyball classes. Therefore, the **purpose** of our study is to characterize the technologies that can be used in volleyball classes to implement differentiated methods of improving players' physical fitness.

Research methods. We used a comparative analysis of approaches to IT use in volleyball, presented in scientific publications, and a content analysis of Internet resources that describe digital tools used by athletes and coaches to support volleyball training.

Results. Let's consider the main areas of application of modern volleyball technologies, which help improve players' technique, optimize tactical training, and prevent injuries. These technologies include video analysis, digital health tools (in particular, motion sensors) for biomechanical analysis, specialized software for tactical analysis, and the use of AI and virtual and augmented reality).

Video analysis in volleyball.

Video analysis is a tool that allows one to study in detail the players' technique, team tactical actions, and opponents' strategies. For this purpose, various video recording and processing systems are used to ensure high image quality, ease of analysis, and the ability to obtain objective data. Video analysis with automatic tagging [12] makes it easier to capture key game moments to develop specific recommendations for players. For video analysis of the technique of performing elements, high-speed cameras are used that allow recording video at a high frame rate, which enables you to analyze fast movements in detail and identify errors in the technique of playing volleyball (in particular, GoPro Hero 12 or iPhone 15 Pro cameras record movements at a frequency of 120 to 1000+ frames per second, so when analyzing the serve, you can study in detail the trajectory of the ball, the position of the player's arm and body, as well as the speed of movement).

Storyboarding and slow-motion software are essential tools for analyzing video footage. It allows

you to split the video into separate frames, view them in slow motion, and stop them at the right time. This lets you study each player's movement in detail and detect errors that cannot be noticed during normal viewing. By tracking the movement of players on the court, you can gain insight into team strategies, player positioning, and individual performance. In particular, the Swin Transformer app [18] can be used to analyze the movements of players in volleyball games, Dartfish allows you to storyboard and then compare movements, build trajectories, Hudl Technique supports slow-motion viewing and provides annotations, Kinovea as a free analog of Dartfish has storyboarding and measurement functions, Coach's Eye comes as a smartphone application with storyboarding and commentary.

Analyzing players' techniques using video allows you to identify errors in performing elements, compare players' techniques with reference samples, and develop individual programs for correcting techniques. For example, when analyzing a serve, you can identify errors such as incorrect hand position, insufficient amplitude of movement, or an inaccurate ball strike. When examining the reception, you can identify incorrect body position, erroneous choice of the point of contact with the ball, or insufficient cushioning. Similarly, when analyzing the passing and attack, you can identify errors in the technique of these elements. Video analysis can be used to study the location of players on the court during various phases of the game, analyze the effectiveness of tactical combinations and strategies, and identify weaknesses in the opponents' defense and offense.

Motion sensors and biomechanical analysis of their performance

Motion sensors play an important role in modern volleyball. They provide important information for analyzing players' techniques [11]. At the same time, biomechanical analysis of movement techniques is an important tool for improving sports performance and preventing injuries in volleyball [6; 7].

It allows you to determine the optimal trajectory of movement during the serve and attack, evaluate the efficiency of muscle use during the jump and landing, and analyze the impact of movement technique on the risk of injury. The optimal trajectory of movement allows you to achieve maximum speed and accuracy of the shot with minimal energy expenditure. Biomechanical analysis allows you to determine the optimal angles, speeds, and accelerations of the arm and body during the serve and attack. Assessing the efficiency of muscle use during jumping and landing is another essential task of biomechanical analysis. Efficient muscle use allows you to achieve the maximum jump height and minimize the load on the joints during landing. The biomechanical analysis will enable you to determine which muscles

work most actively during the jump and landing and assess their strength and endurance. Biomechanical analysis also helps to identify potentially dangerous movements and develop recommendations for their correction.

Several types of motion sensors are used in volleyball, each with its own characteristics and applications.

Technological types (based on the measurement principle) include accelerometers, gyroscopes, and pressure sensors [1].

Accelerometers are one of the most common motion sensors used in volleyball. They measure acceleration and impact loads, which allows you to assess the intensity of players' movements, detect sudden speed changes, and determine the force of impacts. Accelerometers can be used to analyze serving, receiving, passing, and attacking techniques, as well as to monitor the load on players during training and competition. Gyroscopes are another vital type of motion sensor used in volleyball. They measure the angular velocity and orientation of the body, which allows you to evaluate the coordination of movements, determine the position of the body in space, and analyze the technique of rotational movements Gyroscopes can be used to analyze the method of serving, blocking and defense, as well as to improve the coordination and balance of players. Pressure sensors are used in volleyball to analyze the load distribution on the foot. They measure the pressure exerted on different foot parts during jumping, landing, and moving around the court. This data can be used to assess the effectiveness of cushioning, identify uneven load distribution, and prevent foot and ankle injuries.

Functional-environmental types (according to the place of application and tasks) include:

– Inertial sensors (IMU – Inertial Measurement Unit) – measure acceleration, angular velocity, and orientation and analyze jumps (vertical jump, block, attack), hand speed during impact, and body stability during ball reception. Examples of such sensors include DorsaVi (body sensors for biomechanical analysis), Xsens MVN (complete body tracking systems), and Vert (a special sensor for measuring jump height).

– Optical tracking systems (Motion Capture) use cameras and markers to determine the player's position accurately and are used to analyze movement techniques (for example, foot placement when jumping) and 3D modeling of the ball's trajectory. Examples of such sensors are Vicon (a professional system for sports biomechanics) and Qualisys (used in motion research)

– Pressure sensors (for impact and jumping force analysis) are built into the floor (force platforms) or shoes and help measure the repulsive force during

a jump and the leg load distribution. Examples of such systems are Kistler Force Plate (for analyzing jumping dynamics) and SmartSole (shoe sensors)

– GPS trackers (for monitoring movement on the field) measure speed, distance, and activity zones and are used mainly in endurance training. Examples of such systems are Catapult Sports and STATSports Apex.

– Acoustic/vibration sensors (for kick analysis) record the force and accuracy of a kick and can be embedded in the ball or gloves. An example is Blast Motion (sensors for kick analysis).

The table below summarizes these two classifications into one (Table 1).

Data obtained from motion sensors can be used to improve the training process in volleyball [8].

They allow you to monitor the load on players during training and competitions, individualized training programs based on the player's physical condition, and develop exercises to improve coordination and balance. Monitoring the load on players during training and competition is an essential aspect of using motion sensor data. Motion sensors can measure movement intensity, the number of jumps, runs, kicks, heart rate, and activity level. This data can be used to assess the load on players and prevent overtraining.

Differentiating training programs based on player fitness data is another crucial aspect of using motion sensor data. Motion sensors can assess players' physical condition, strength, endurance, coordination, and balance. These exercises can include balancing on one leg, performing jumps with turns, and using special simulators to develop coordination.

Application of AI in volleyball

Precision motion tracking systems that can be used to improve volleyball training include the following technologies:

– KINEXON PERFORM (https://kinexon-sports.com/sports/volleyball). The local positioning system provides an accuracy of less than 10 cm and allows you to track players' movements in real-time without interruption. It is suitable for analyzing player positions and tactical actions during training and matches. Inertial Measurement Units (IMUs) allow you to track player loads on the go, analyze their movements, and determine training needs. This system adapts to any environment and does not require wired installations.

– Motion Capture systems. Technologies such as Rokoko (https://www.rokoko.com/insights/motion-capture-in-sport) create real-time 3D models of athletes' movements. This allows you to analyze the technique of performing elements, identify weaknesses, and optimize micromovements to improve performance. Using marker suits and cameras provides accurate data on joint angular displacements and muscle activity, which enhances technical elements such as serving or blocking.

– Pixellot AI Tracking (https://www.pixellot.tv/sports/volleyball/). This system uses artificial intelligence algorithms to capture and analyze video of matches automatically. It provides a multi-camera view of the game, automatic zooming of essential moments, and statistical data integration. It is suitable for training and match analysis thanks to the ability to create personalized video reviews.

– Catapult Vector (https://www.catapult.com/solutions/athlete-monitoring). The system integrates GPS, LPS, and heart rate sensors to monitor athletes' physical parameters. The system uses machine learning to analyze data and provide individualized recommendations for exercise and recovery, providing accurate analysis of loads and injury risks, which helps optimize the training process.

– Computer tracking FIVB (https://www.youtube.com/watch?v=TVOply3J3eo). A system that uses cameras to track players and the ball on the court in 3D. It provides accurate information about the speed of the ball, player positions, and key moments of the game (e.g., serve or attack).

Table 1

Combination of technological and functional-environmental classifications of sensors in volleyball

Technological classification	Functional and environmental classification	Where is it used?	Examples of systems/ devices	What does volleyball measure?
Accelerometer	Inertial sensors (IMU), GPS trackers	On the body (arms, torso, legs), balls	Vert, DorsaVi, Catapult Sports	Impact force, jump height, movement speed
Gyroscopes	Inertial sensors (IMU), optical systems	Combined with IMU, smart balls	Xsens MVN, Blast Motion	Body rotation, ball trajectory (topspin)
Vise sensors	Platforms of power, Smart shoes	Floor (force plates), shoes	Kistler Force Plate, SmartSole	Repulsive force, balance when landing
IMU (accelerometer + gyroscope)	High-speed cameras + analysis software	Training systems	Vicon, Qualisys + Dartfish	Complete biomechanical analysis of movements

The benefits of using this system include [3] include accuracy (precision data allows for detailed analysis of movements), personalization (systems adapt to the needs of each player), injury prevention (proactive analysis of movements helps to identify potentially dangerous technical errors), and performance improvement (optimization of technique and tactics). Such technologies significantly increase the effectiveness of volleyball training and make it more informed and personalized.

A personalized approach to monitoring involves taking into account the individual characteristics of each athlete, such as age, weight, training level, and position on the court. Machine learning is used to classify technical actions (serve, block, hit) when deep neural networks automatically evaluate the effectiveness of training [17].

Machine learning can identify individual indicators of training load and well-being that may predict the occurrence of overload in a particular volleyball player. This allows you to adjust the training process promptly and prevent injuries. Monitoring and evaluating the effectiveness of tactical decisions are essential to analyze the effectiveness of various tactical schemes during the game, assess the impact of tactical changes on the course of the match, and identify trends in the team's and opponents' play. Evaluating the effect of tactical changes on the course of the game is the next stage of monitoring and assessing the effectiveness of tactical decisions. The software allows you to analyze the course of the match and determine which tactical changes were effective and which did not bring the desired result.

The use of virtual reality technologies in volleyball

The use of virtual reality (VR) technologies in volleyball provides the possibility of realistic simulations of game situations and, at the same time, a safe environment for practicing techniques and tactics, along with improving players' reactions and decision-making skills in a limited time [16].

Creating realistic simulations of game situations is one of the key features of VR for volleyball training. VR technologies allow you to create virtual platforms that reproduce real game conditions as accurately as possible. Players can see virtual opponents, hear the game's sounds, and feel the tension of the match. This allows them to train in conditions as close to real life as possible and improve their skills. Practicing techniques and tactics in a safe environment is another important feature of VR for volleyball training. VR technologies allow players to practice the following elements [14], such as serving, receiving, passing, and attacking, without the risk of injury. They can also practice tactical combinations and strategies in a safe environment without fear of making mistakes. Improved reaction and decision-making under time constraints is another advantage of using VR for volleyball training.

VR simulators are specialized programs designed to improve volleyball techniques using virtual reality. Serving, receiving, and passing simulators are some of volleyball's most common VR training devices. To practice serving, the simulator can show the ball's trajectory, flight speed, and accuracy of the shot and advise on improving the technique. Simulators for improving blocking and attacking skills are another type of VR simulator that allows players to practice blocking and attacking skills (for example, a blocking simulator can show the trajectory of the ball and the actions of the attacker and give advice on choosing the right position and timing of the jump). Interactive programs for the development of coordination and reaction speed are another type of VR simulator. They can allow players to perform complex movements of arms and legs in a virtual environment. A program to develop reaction speed can require players to respond quickly to changes in the game and make the right decisions. VR technologies can also be used for rehabilitation after volleyball injuries, helping players restore motor skills in a controlled environment, reducing the fear of returning to the game after an injury, and improving their psychological state during rehabilitation.

Thus, modern IT opens up new opportunities for personalizing the training process, taking into account each player's individual characteristics. Tools like video analysis, biomechanical sensors, artificial intelligence, virtual reality, and machine learning allow one to record indicators and adapt the load, technique, and training strategy to a specific athlete. Video analysis allows you to study the player's movement technique in detail, compare it with reference samples, and identify errors that may be invisible during a standard training session. Based on this data, the coach can develop individualized corrective exercises to eliminate weaknesses. Motion sensors and biomechanical analysis objectively assess physical performance, such as reaction time, jumping power, or kicking accuracy. This data allows us to determine each player's training level and form groups with similar needs. Artificial intelligence and machine learning enable automating the analysis of large data sets, predicting the effectiveness of various training programs, and offering optimal solutions for each player. Virtual reality technologies create simulated game situations where players can practice specific skills in a controlled environment. This is especially useful for differentiating training.

Discussions. The use of information technologies in volleyball is a highly relevant approach to implementing differentiated methods of improving players' physical fitness. Firstly, objective data increases the efficiency of the training process. Instead of subjective assessments by the coach, technology provides accurate information about the

players' technique, physical condition, and tactical actions. This allows for the individualization of training programs and the focus on those aspects that need improvement. Second, using technology increases the team's competitiveness by improving tactical training. Analyzing large amounts of data about the team's and opponents' play allows you to identify strengths and weaknesses, develop effective tactical plans, and predict game outcomes. This allows the team to better prepare for the match and increase its chances of winning. Third, technology helps prevent injuries by analyzing the biomechanics of movements. Motion sensors and motion analysis software can detect incorrect movements and assess the risk of injury. This data can be used to develop individualized injury prevention programs and improve players' movement techniques.

One of the key areas is the analysis of video and motion sensors to improve players' technique. High-speed cameras allow for a detailed analysis of the method of elements such as serving, receiving, passing, and attacking. Storyboarding and slow-motion software allow you to identify errors in technique and compare them to reference patterns. Motion sensors, such as accelerometers and gyroscopes, measure the player's body's acceleration, angular velocity, and orientation during movements. This data is used to biomechanically analyze the technique and assess the efficiency of muscle use. Another important area is using software for tactical analysis and game strategy. Programs for collecting and processing statistical data allow you to analyze large amounts of information about the team's and opponents' performance. Tools for visualizing tactical schemes and strategies help coaches develop effective game plans and predict game outcomes based on data analysis. Such software allows you to study the location of players on the court during different phases of the game, analyze the effectiveness of tactical combinations and strategies, and identify weaknesses in the defense and offense of opponents. Using virtual reality to train and simulate game situations is a promising area in volleyball. VR simulators allow the creation of realistic simulations of game situations in which players can practice techniques and tactics in a safe environment VR technology can be used to practice serving, receiving, and passing, improve blocking and attacking skills, as well as develop coordination and reaction speed In addition, VR can be used for rehabilitation after injuries, restore motor skills under controlled conditions and reduce fear of returning to the game.

In addition to the above areas, digital technologies can be used in volleyball to improve sports nutrition and assess and monitor energy availability in athletes [5]; Increasing athletes' motivation; improving communication between coaches and players.

Conclusions. The modern development of digital technologies creates fundamentally new opportunities for transforming the training process in volleyball, the transition from generalized approaches to differentiated training of players. The analysis of modern technological solutions demonstrates that their implementation allows not only the supplementation of traditional methods but also radical changes in the philosophy of sports training by implementing a deeply differentiated approach.

The key advantage of technological solutions is the ability to provide continuous monitoring and comprehensive assessment of individual player performance. Video analysis, in combination with biomechanical sensors, allows us to detect microbalances in performing elements that cannot be identified visually. Intelligent artificial intelligence and machine learning systems transform the collected data into personalized training algorithms. These systems are able to predict optimal loads, determine the periodization of training, and even predict the risk of injury for a particular player. Virtual reality technologies open up a new dimension in the differentiation of the training process. They allow you to create game scenarios that simulate specific tactical situations requiring differentiated improvement.

Development prospects are associated with the further integration of biometric data, advanced analytical functionality, and the creation of intelligent training systems. This will allow us to move from simple differentiation to full-fledged personalization of the training process, where each element of the training will be adapted to a particular player's individual characteristics and goals as accurately as possible. Thus, digital technologies are becoming a tool and a key factor in creating a new paradigm of sports training in volleyball.

BIBLIOGRAPHY
1. Alzahrani A, Ullah A. Advanced biomechanical analytics: Wearable technologies for precision health monitoring in sports performance. Digit Health. 2024 May 27;10:20552076241256745. doi: 10.1177/20552076241256745
2. D. Surin, A. Zaikina, O. Shukatka, N. Oliinyk and O. Semenikhina. Digital Public Health Tools: an Attempt at Classification Within Ukrainian Practices. *2024 47th MIPRO ICT and Electronics Convention (MIPRO)*, Opatija, Croatia, 2024, pp. 425–429, doi: 10.1109/MIPRO60963.2024.10569203
3. Damji F., MacDonald K., Hunt M.A., Taunton J., Scott A. (2021) Using the VERT wearable device to monitor jumping loads in elite volleyball athletes. PLOS ONE 16(1): e0245299. https://doi.org/10.1371/journal.pone.0245299

4. de Leeuw, A.-W., van der Zwaard, S., van Baar, R. and Knobbe, A. (2022), Personalized machine learning approach to injury monitoring in elite volleyball players. *European Journal of Sport Science,* 22: 511–520. https://doi.org/10.1080/17461391.2021.1887369

5. MK, Magee, BL, Lockard, HA, Zabriskie, AQ, Schaefer, JA, Luedke, JL, Erickson, MT, Jones, and AR, Jagim. 2020. «Prevalence of Low Energy Availability in Collegiate Women Soccer Athletes. https://doi.org/10.3390/jfmk5040096

6. Ozawa Y, Yamada H, Ozawa S, Vogt T, Kanosue K. Biomechanical analysis of distance adjustment in volleyball overhead pass. *Sports Biomech.* 2022 Oct 7:1–18. doi: 10.1080/14763141.2022.2125427. Epub ahead of print. PMID: 36205520.

7. S. Yabukami et al., «Motion capture system of magnetic markers using three-axial magnetic field sensor,» in IEEE Transactions on Magnetics, vol. 36, no. 5, pp. 3646–3648, Sept 2000, doi: 10.1109/20.908928

8. Salim FA, Postma DBW, Haider F, Luz S, van Beijnum BF, Reidsma D. Enhancing volleyball training: empowering athletes and coaches through advanced sensing and analysis. *Front Sports Act Living.* 2024 Apr 16;6:1326807. doi: 10.3389/fspor.2024.1326807

9. Semenikhina, O. V., Yurchenko, A. O., Rybalko, P. F., Shukatka, O. V., Kozlov, D. O., & Drushliak, M. H. (2022). Pidhotovka maibutnikh fakhivtsiv fizychnoi kultury i sportu do vykorystannia zasobiv digital health u profesiiini diialnosti. *Informatsiini tekhnolohii i zasoby navchannia*, 89(3), 33–47. https://doi.org/10.33407/itlt.v89i3.4543

10. Song, X. Physical education teaching mode is assisted by an artificial intelligence assistant under the guidance of a high-order complex network. *Sci Rep* 14, 4104 (2024). https://doi.org/10.1038/s41598-024-53964-7

11. Sousa, A. C., Marques, D. L., Marinho, D. A., Neiva, H. P., & Marques, M. C. (2023). Assessing and Monitoring Physical Performance Using Wearable Technologies in Volleyball Players: A Systematic Review. *Applied Sciences*, 13(7), 4102. https://doi.org/10.3390/app13074102

12. Taban, Z., & İmamoğlu, M. (2023). The Effect of Interactive Videos on Volleyball Education. *Journal of Learning and Teaching in Digital Age*, 8(2), 267–275. https://doi.org/10.53850/joltida.1211628

13. Taborri, Juri, Keogh, Justin, Kos, Anton, Santuz, Alessandro, Umek, Anton, Urbanczyk, Caryn, van der Kruk, Eline, Rossi, Stefano, Sport Biomechanics Applications Using Inertial, Force, and EMG Sensors: A Literature Overview, *Applied Bionics and Biomechanics*, 2020, 2041549, 18 pages, 2020. https://doi.org/10.1155/2020/2041549

14. U. Gong, H. Jia, Y. Wang, T. Tang, X. Xie and Y. Wu, «VolleyNaut: Pioneering Immersive Training for Inclusive Sitting Volleyball Skill Development», 2024 IEEE Conference Virtual Reality and 3D User Interfaces (VR), Orlando, FL, USA, 2024, pp. 1022–1032, doi: 10.1109/VR58804.2024.00121

15. Wang Y, Wang X. Artificial intelligence in physical education: comprehensive review and future teacher training strategies. *Front Public Health*. 2024 Nov 8;12:1484848. doi: 10.3389/fpubh.2024.1484848

16. Witte K, Bürger D, Pastel S. Sports training in virtual reality with a focus on visual perception: a systematic review. Front Sports Act Living. 2025 Mar 20;7:1530948. doi: 10.3389/fspor.2025.1530948

17. Yu, Zhida, Zhong, Yuanyuan, Shao, Zhe, Application of Machine Learning and Digital Information Technology in Volleyball, *Mobile Information Systems*, 2022, 7080579, 11 pages, 2022. https://doi.org/10.1155/2022/7080579

18. Z. Liu et al., «Swin Transformer: Hierarchical Vision Transformer using Shifted Windows», 2021 IEEE/CVF International Conference on Computer Vision (ICCV), Montreal, QC, Canada, 2021, pp. 9992–10002, doi: 10.1109/ICCV48922.2021.00986