Chapter 8

Innovative Technologies in Volleyball

Beyza Akyüz[1]

Summary

Volleyball is an intermittent sport that involves many explosive movements both vertically and horizontally, where flexibility and coordination are very important as well as strength and power. In order to achieve optimal performance, players must have high quality requirements in terms of physical, physiological and technical aspects.

As in all areas of life, the use of technology occupies an important place in volleyball. Support is received from innovative applications and devices such as wearable technologies, VR-AR, smart devices for physical and physiological monitoring of athletes, directing training programs in the light of the data obtained, preventing sports injuries and improving performance.

Developments in the field of information technologies continue to increase their widespread impact in different areas of life day by day. With the integration of technology into the sports world, the same widespread effect has made a sharp acceleration in volleyball sport as in many sports branches. In the process of training planning and performance evaluation, which extends from technique teaching to performance development, some applications and methods are frequently used in today's technology. Performance measurements, evaluation of measurement results and programming of training in the light of the data obtained, on the other hand, there have been great breakthroughs in issues such as protection from sports injuries.

Volleyball is one of the sports in which technology is used intensively. Data from technological devices used during training provide detailed information about the athlete's movement patterns, physiological processes and performance components (Windt et.al;2020). On the other hand, in a competitive environment, many statistical data can be accessed, such as

1 Fenerbahçe University, Faculty of Sports Science / Istanbul, e-mail: beyza.akyuz@fbu.edu.tr
ORCID: 0000-0001-9740-2177

https://doi.org/10.58830/ozgur.pub315.c1483

distance covered by the athlete, movement path, successful and unsuccessful attack and defence zones, quantitative data on attack and defence in these zones, ball speed and ball trajectory. In this way, the strengths and weaknesses of the player and the team can be analyzed, the necessary improvements and developments can be made by processing the data obtained and incorporating them into the training programme, and performance can be improved.

Volleyball technologies, from wearable devices to smart balls, from data analytics to video analysis systems, are a growing trend that we see frequently on the courts to meet the needs of the game in all areas. Thanks to wearable sensors, cameras that report location and speed, real-time information about the player can be accessed.

Wearable technologies

Wearable technologies collect input signals from wearable sensors attached to the human body and are often used to monitor and assess exercise load. The devices used in wearable technologies include sensitive sensors, global positioning system (GPS) devices, accelerometers, gyroscopes, and magnetometers (Sousa et al, 2023; Haider, 2020). The use of these devices requires the application of various algorithms and filters. Elite athletes in particular often use these devices to measure external training loads. Total distance is a commonly used parameter in the calculation of external load and GPS data is used in this calculation. The distance travelled is calculated according to certain speed thresholds. Accelerometers, on the other hand, measure acceleration on the X-Y-Z axes and have been used in smart watches and mobile phones for many years (Bergün, 2009; Cardinale, 2017).

In volleyball serving or spiking technique, the angular velocity of the arm during the arm pull, the phase of meeting the ball and then the phase of following the ball, the acceleration, and the ability to execute the movement quickly are important to complete the attack without being caught by the opposing team's block. For this reason, acceleration at the shoulder, elbow and wrist is a parameter that should be measured. It is then important for the athlete's development to include arm acceleration exercises in training. Wearable technology devices include magnetometers and gyroscopes, which measure direction, orientation, and angular velocity respectively. Due to the nature of volleyball and the tactical maneuvers used, the spiker must move at different angles and angular speeds at the net to avoid being caught by the opposing team's block or to surprise the block, while the defender has to accelerate and decelerate in different directions. At this point, instantaneous data from GPS, accelerometer and gyroscope wearable technology devices actually reflect the footprints left by the player during the match.

Wearables and sensors track players in real time, collecting a wide range of data, including metrics such as heart rate, fatigue, jump performance, distance travelled, acceleration and deceleration during training or a match while the ball is in play. Some wearable devices with built-in accelerometers, gyroscopes and magnetometers enable the measurement of load. The algorithm used by the device provides the vertical displacement data of the athlete (Damji et.al, 2021). This is important data for volleyball, where jump height is critical.

As the sensors used are very light and designed not to interfere with the athlete's movement, they have no negative impact on performance. Based on the data collected, performance can be assessed, and the training programme can be adjusted to optimize performance. Biometric T-shirts provide information about the player's posture, body symmetry and muscle fatigue, body temperature and hydration levels through sensors on the shirt. Some groups of wearable devices provide feedback focused on recovery data. This allows the coach to monitor the player's recovery process in detail. The use of accelerometers and gyroscopes, which collect data on acceleration, balance and rotation, is also quite common, providing the coach with information for monitoring and protecting the player in terms of preventing sports injuries, as well as providing biomechanical analysis of the player.

Video analysis system

Vision based methods recognize selected activities using several computers. (Haider,2020) Thanks to high-resolution cameras placed in different parts of the field, the positions in the game are recorded from different angles. This allows the individual performances of the players as well as team tactics to be analyzed and strategies to be determined instantly. Thus, the coach can analyze not only his own team but also the opposing team tactically and take measures against the opponent in order to achieve an optimal result and create a tactical understanding in this direction. Video analysis systems are also used to verify the position in case of team appeals during the referee's decision-making process during the match, which supports the development of a fair match management and sound decision-making mechanism.

During the match, a single interface allows tactical analysis of the teams and instant statistical information to be shared with the bench and the media. This feedback can be used to make immediate changes to the team's tactical maneuvers in order to exploit the opponent's weaknesses or to take measures against the opponent in the coach's own team order. With this invaluable information at your fingertips, the fate of the match can change at a moment's notice.

Movement analysis provides data such as the way the athlete uses the technique or the frequency of the movement. Metrics such as distance covered during training or competition, number of sprints, frequently performed movements are analyzed and in this way the athlete's training load can be calculated. An injury analysis can be obtained by comparing the athlete's movement analysis, frequently performed movements, training load data with periods of sports injury. The aim is to use the data obtained to reduce the risk of sports injuries. In other words: o Movement patterns that can lead to overuse injuries can be identified and corrective action can be taken. These systems not only improve the player's performance but also minimize the risk of injury.

In addition, volleyball-specific analysis programmes are often used, allowing coaches to create small clips from uploaded game footage, add annotations, share, and work with team players, and enable communication between coaches. It provides player performance statistics, match reports and player feedback.

An important aspect of the technologies used in volleyball is the need to be able to determine the camera position with a high degree of accuracy without having to make any changes to the court, ball, or net. For this reason, the use of multi-camera systems has become widespread. The best known and most widely used multi-camera system in tennis is the Hawk-Eye system. This system estimates the position of the ball in each set of frames collected (Szelag, et.al 2019).

In volleyball, many algorithms have been used to track the ball or the player in match analysis. Even machine learning is used in some algorithms. If we have to define machine learning, we can say that it is computer programs that can improve their processing power by themselves based on experience. When the effect of athletic level of volleyball players on decision making, accuracy, reaction time and cognitive level in hitting, landing, and blocking was analyzed by machine learning method, it was concluded that the higher the athletic level, the less the players were affected by other factors (Yu et al, 2022). However, factors such as motion blur due to ball speed, low camera frequency or noisy ball contour (excessive exposure time causes blurring and stretching of the ball contour), lighting or changing environmental conditions (player and spectator movements in the background) can reduce accuracy.

For match analysis, some software is used to analyze the percentages of players and positions during the match. The software provides information on the percentage of successful and unsuccessful moves in parameters such

as attacking combinations (side-out and counterattacking), ball reception, defence, block, service, digs and setting. In addition, a statistical report is obtained about the success percentages of players or teams and positions on the court (Kurowski et.al, 2018; Silva et.al, 2014).

Hawk eye and Challange system

The Hawk Eye and Challenge System has been a popular image analysis system for volleyball matches in recent years. The fast pace of the game makes it difficult for referees to make decisions. This situation is sometimes a topic of discussion for the teams and spectators and can lead to tension in the competition environment, increasing the pressure on the referees. For this reason, the use of Hawk eye and challenge systems has been introduced to make decisions in critical situations more reliable and referee decisions more objective and has made a great contribution to the sport of volleyball.

It is sometimes difficult for the referee to decide whether the ball is in or out when it is travelling at high speed. The Hawk Eye system has been used in many industries for a long time. It is an accurate and reliable system, and the aim of Hawk Eye is to monitor the trajectory of the ball throughout the match (Singh & Dureja, 2012). Thanks to this system, information such as whether the ball is in contact with the line and the distance to the line can be clearly seen by the cameras that monitor the lines of the pitch.

The challenge system has been used by the Turkish Volleyball Federation since the 2017-2018 season. According to the rules of the game, at the end of a rally, if one of the teams disagrees with the referee's decision, it can request a challenge according to the rules. The actions that can be requested are ball in/ball out, block contact, net contact, line violation (service line, attacking line, centre line) and four balls. Teams have two appeals per set. However, if the teams' objections are justified, their right to appeal continues throughout the set. (TVF, 2018).

According to the results of the requested challenge analysis of the Turkish Volleyball Federation (TVF, 2019) for the first half of the 2018-2019 season, it was reported that 612 challenges were requested in 132 matches played in the first half. In 370 (60.46%) of these challenges, the referee's decision was correct and in 242 (39.54%) of these challenges, the teams were correct. Teams requested challenges 1.24 times per set and 3.73 times per match. Challenge results were displayed on the screen in an average of 39.5 seconds. According to the statistics, the time used for challenges was 2.86% of the total time. According to the challance results, it was determined that 85% of the referees were right about centre line and attacking line infringements

and 67% of the teams were right about aerial contact (TVF, 2019). In another study on team appeals and referee justification rates in the use of the challenge system, an analysis of challenges was conducted, and referee justification rates were determined for the 2020/2021 and 2021/2022 women's and men's Super League competitions. The challanges made by the teams were analyzed with the Video Evaluation System (GDS) and it was stated that the rate of justification of the referee's decisions was higher than the teams in decisions other than four strikes, and it was also stated that technological tools that help the referee's decision have a positive effect on the referee's performance (Akarçeşme, 2023; TVF, 2017; TVF, 2018).

Virtual Reality (VR)

Thanks to Virtual Reality (VR) and Augmented Reality (AR) simulation technologies, players can train in a simulated volleyball match in a virtual environment, without the pressure of a real competition, experiencing different scenarios and developing strategies to suit the situation. The technique used can be visualized from different angles and focused on more detail. Individual and team tactics for competition can be repeatedly practiced in visual form. VR can also enable coaches to give real-time feedback to players and train them remotely.

Augmented Reality (AR)

During a volleyball match, real-time statistical information about the players or the game on the screen increases the motivation and enjoyment of the spectators. The spectators feel more involved in the game and can better understand the details of the game. In addition to statistical information, AR can also be used to model players' positions and analyze strategies. When we talk about the contributions of AR and VR technologies in volleyball, we can mention the increase in repetitions for the player, the development of muscle memory and thus technical development, the possibility of identifying new strategies and trying them out for the coach, and the possibility of being more involved in the game and increasing the enjoyment of watching for the spectators.

Smart Equipments

The use of technology in volleyball is not limited to observing, measuring, and evaluating performance, but many smart devices are also used to improve technique. One of these is the smart volleyball. In particular, the serve, which can be considered as a kind of attacking method because it is the first movement that starts the game, has a very important place in today's volleyball. The ace points that the players get directly from the serve

are important both in terms of scoring and team motivation. From this point of view, the information that can be obtained about the point at which the ball is hit, that is, the falso to be given to the ball and the speed of the ball, is advantageous in terms of improving the serving technique. This is where technology comes in, and smart balls equipped with smart sensors come into play. Thanks to these sensors, data on the speed, direction, spin and impact points of the ball help coaches to improve technique (Zhang et.al, 2022). Not only the speed but also the accuracy of the ball is important when serving or dunking. Therefore, having information about the trajectory and speed of the ball allows the player to improve the technique in these parameters. On the one hand, the devices that have been used for years to measure the speed of the ball are now being used to measure the speed of the serve or dunk. Smart coaching platforms, which allow coaches and technical staff on and off the court to communicate with each other to make immediate changes and adjustments to the course of the game, are also becoming more common.

Artificial Intelligence

Artificial intelligence, which was developed as a sub-science of computer science and whose use is increasing every day in many fields, from healthcare to the automotive industry and education, is also being used in the field of sport. It is based on the development of behavioral and computational systems that allow data to be collected in situations of perception, reasoning, learning and decision-making. For example, the mental training used by volleyball players is of great importance in achieving optimal results and improving performance. It is believed that maintaining the players' psychological modes at a certain level will contribute to the optimization of their sporting skills. In this context, an artificial intelligence model has been developed to increase the accuracy of mental training models. This model is based on artificial intelligence calculations and aims to predict neural networks, short-term memory, and long-term memory (Jin, 2022). On the other hand, Shih et al (2022) categorized the artificial intelligence-based smart technologies used in volleyball under 3 main headings and listed them as monitoring, evaluation, and diagnosis respectively. Monitoring is defined as the monitoring of the athlete's physiological data, while evaluation and diagnosis is the evaluation of the data obtained from the athlete using artificial intelligence, discovering the athlete's potential, and making a judgement about it. As a result of all this process, it was stated that players receive immediate and accurate feedback during the training process with intelligent technology, which has a positive effect on learning.

Promotion and Dissemination of Sports

Thanks to Augmented Reality (AR) or various interactive applications, spectators can watch the game as if they were there, even if they are not in the competition area, and feel involved in the game and the environment.

In addition, the statistical information about the athletes and the tactical analysis of the game projected on the screen during volleyball matches increases the spectators' understanding of the game, makes them feel more involved in the game and allows them to follow the game as they understand it. With the increasing number of spectators, it helps to increase the audience and popularity of the sport.

CONCLUSION

As a result, the integration of volleyball with technology has made a significant contribution to enriching the experience of players, coaches and even spectators. Increasing the technical capacity of the player by analyzing performance, identifying, and improving weaknesses, and making appropriate strategic moves immediately to achieve the optimal result are among the results provided by the use of technology in volleyball. On the other hand, it is crucial to determine the training load, given that overloading can lead to sports injuries. Therefore, it is necessary to determine the training load in a healthy way and to plan the training within this framework. At this point, technological devices provide the opportunity to make valid and reliable measurements (Windt et. al, 2020).

The role of technology in the development of game dynamics and tactical strategies, in ensuring the interest and followership of spectators, in bringing sport to the masses and popularizing it cannot be denied. In parallel with the rapid development of technology in the coming times, it is a matter of curiosity what kind of technological devices and applications can be used in volleyball.

REFERENCES

Akarçeşme, C., Hasan, A. K. A., Aktuğ, Z. B., Serkan, İ. B. İ. Ş., & Altundağ, E. (2023). Voleybolda Uygulanan Görüntülü Değerlendirme Sistemi Üzerine Bir Analiz. *Gazi Beden Eğitimi ve Spor Bilimleri Dergisi*, *28*(1), 73-77.

Bergün, M., Mensure, A., Tuncay, Ç., Aydin, Ö., & Çigdem, B. (2009). 3D kinematic analysis of overarm movements for different sports. *Kinesiology*, *41*(1), 105-111.

Cardinale, M., & Varley, M. C. (2017). Wearable training-monitoring technology: applications, challenges, and opportunities. *International journal of sports physiology and performance*, *12*(s2), S2-55.

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, e0245299.

Haider, F., Salim, F. A., Postma, D. B., Van Delden, R., Reidsma, D., van Beijnum, B. J., & Luz, S. (2020). A super-bagging method for volleyball action recognition using wearable sensors. *Multimodal Technologies and Interaction*, *4*(2), 33.

Jin, X. (2022). Feasibility Analysis and Countermeasures of Psychological Health Training Methods for Volleyball Players Based on Artificial Intelligence Technology. *Journal of Environmental and Public Health*, *2022*.

Kurowski, P., Szelag, K., Zaluski, W., & Sitnik, R. (2018). Accurate ball tracking in volleyball actions to support referees. *Opto-Electronics Review*, *26*(4), 296-306.

Shih, C. H., Huang, T. C., & Li, C. (2022, October). Applying Smart Technology To Volleyball training. In *2022 IEEE 4th Eurasia Conference on IOT, Communication and Engineering (ECICE)* (pp. 215-218). IEEE.

Singh Bal, B., & Dureja, G. (2012). Hawk Eye: A Logical Innovative Technology Use in Sports for Effective Decision Making. *Sport Science Review*, *21*.

Silva, M., Lacerda, D., & João, P. V. (2014). Game-related volleyball skills that influence victory. *Journal of human kinetics*, *41*, 173.

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.

Szelag, K., Kurowski, P., Bolewicki, P., & Sitnik, R. (2019). Real-time camera pose estimation based on volleyball court view. *Opto-Electronics Review*, *27*(2), 202-212.

Turkish Volleyball Federation (TVF) https://www.tvf.org.tr/duyurular/gds-yayini-hakkinda/ February 8, 2019 Access date: 03.07.2023.

Turkish Volleyball Federation (TVF) Application Principles of Video Evaluation System (2018) www.tvf.org.tr/_dosyalar/MHGK_Belgeler/2018_gds_talimati.pdf. Access date: 01.07.2023

Turkish Volleyball Federation (TVF) Refereeing Guide and Instructions (2017). http://www.tvf.org.tr/_dosyalar/MHGK_Belgeler/hakemlik_rehberi_ve_talimatlari_turkce_2017.pdf. [Access date: 19.07.2023].

Yu, Z., Zhong, Y., & Shao, Z. (2022). Application of Machine Learning and Digital Information Technology in Volleyball. *Mobile Information Systems*, *2022*.

Zhang, T., Jiao, C., Sun, H., & Liang, X. (2022). Application of Internet of Things Combined with Wireless Network Technology in Volleyball Teaching and Training. Computational Intelligence and Neuroscience, 2022.

Windt, J., MacDonald, K., Taylor, D., Zumbo, B. D., Sporer, B. C., & Martin, D. T. (2020). "To tech or not to tech?" A critical decision-making framework for implementing technology in sport. *Journal of Athletic Training*, *55*(9), 902-910.