ENHANCING ATHLETIC PERFORMANCE THROUGH WEARABLE TECHNOLOGY INTEGRATION IN VOLLEYBALL: A PILOT STUDY

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Abstract:

This article investigates the technical and practical aspects of using Kinexon IMU technology and acceleration load evaluation in volleyball monitoring to improve athletic performance and training prescription. The focus is on integrating these technologies to maximise training efficiency and improve player performance. The research highlights the importance of wearable sensors and acceleration metrics in capturing real-time player movement data, which can enhance training strategies and reduce injury risks. By utilising acceleration-based workload monitoring, coaches and sports scientists can personalise training programs, manage workload effectively, and prepare athletes for varying intensity and volume scenarios. The study measures physical demands and workload distribution using metrics such as Accumulated Acceleration Load and Accumulated Acceleration Load per minute. These metrics are beneficial for optimising athlete development and performance in elite volleyball teams at the national level. The findings underscore the transformative impact of using Kinexon IMU technology in external volleyball monitoring, providing valuable insights for structuring training sessions, managing training intensity, and optimising performance outcomes.

Keywords:

Kinexon, Accumulated Acceleration Load, Accumulated Acceleration Load per minute, Volleyball.

INTRODUCTION

Advancements in technology have revolutionised sports performance analysis and athlete monitoring. [1, 2]. Innovative technologies have become essential in volleyball, a sport that demands accuracy, agility, strength, and coordination, for gaining insights into player movements and performance metrics [3]. The integration of wearable sensors, such as Kinexon Inertial Measurement Units (IMUs), VERT, and Catapult, has modernised the way in which detailed kinematic data is captured during training and competitive matches [3, 4, 5, 6, 7].

The world of sports is gradually embracing objective and data-driven decision-making. To meet this growing demand, Kinexon IMU technology has been easily integrated with volleyball monitoring [3, 1]. This integration represents a significant leap forward in unlocking athlete's full potential, improving training methodologies, and increasing our understanding of the kinematical and physiological demands of the game and training itself.

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This study aims to contribute to the expanding knowledge base on wearable sensor technology in sports, specifically focusing on its application in external volleyball monitoring through Kinexon IMUs.

It focuses on transferring data from match analysis to training prescription to enhance training effectiveness. It broadly evaluates this technology's potential benefits and implications for coaches, athletes, and sports scientists. By utilising Kinexon IMUs, coaches and sports scientists can capture real-time data on player movements, jumps, accelerations, and impacts [3]. This data can then be analysed to inform training strategies, optimise performance, and minimise injury risks in volleyball players.

Figure 1 illustrates the Kinexon system containing a docking station and wearable sensors. These sensors, weighing just 15g, function as a 3-axis accelerometer with a range of ±16G sampled at 1 KHz. Additionally, they possess a 3-axis gyroscope with a range of ±4000 deg/sec at 200Hz and a 3-axis magnetometer with a range of ±16 μT at 100Hz. The KINEXON Sensor Network consists of Kinexon Anchors, which enable real-time data tracking. The KINEXON OS platform also captures real-time acceleration data and facilitates dynamic workflows.

1.1. OPTIMIZING ATHLETIC PERFORMANCE THROUGH INDIVIDUALIZED TRAINING REGIMENS BASED ON ACCELERATION LOAD MONITORING

A literature review investigated the usefulness of acceleration load for monitoring training volume and intensity in sports [1, 2, 8, 9]. The focus was on studies that used acceleration metrics for workload assessment and the precision of training volume and intensity.

Synthesising previous research showed that acceleration load metrics, such as Player Load [3, 5], impacts per minute [3], and high-intensity accelerations [3, 5], are significant in quantifying the physical demands of training sessions. Using Kinexon IMU technology, coaches and sports scientists can tailor training volumes and intensities based on real-time acceleration data. This enables precise workload management, customised training prescriptions for each athlete or group of athletes, and the preparation for wrist case scenarios. Also, tracking technology in volleyball practice can help coaches and medical personnel gain valuable insights into an athlete's movement patterns and kinematics, leading to more precise return-to-play (RTP) evaluations. This methodology utilises data to recommend specific training and possible playing strategies for athletes during their return to the field period. It aims to provide a structured approach to the RTP process by incorporating objective data-driven criteria and going away from time-based criteria [8].

The integration of acceleration load analysis with Kinexon IMU technology presents a potent solution for tracking training volume and intensity in sports and explaining individual differences.

By leveraging advanced acceleration metrics, coaches and sports scientists can craft tailored training programs, identify individual potential injury risks, and optimise performance outcomes with enhanced precision. This research underscores the importance of acceleration-based workload monitoring in enhancing athlete development and performance optimisation, emphasising the critical role played by Kinexon IMU technology in modern sports science practices.

Figure 1. Kinexon system.

In sports science, "Accumulated Acceleration Load" refers to the total acceleration an athlete experiences over a specific time frame, whether during training or competition. The IMU's three acceleration axes (x, y, z) are added to determine this metric [9]. This measurement offers valuable information about an athlete's physical stress and workload due to accelerative movements.

The term "Accumulated Acceleration Load per Minute" is used to describe the rate at which acceleration load builds up over time [3]. This measurement calculates the amount of acceleration load an athlete experiences every minute. By dividing the accumulated acceleration load by the duration of the activity in minutes, sports scientists can estimate the average intensity of accelerative movements sustained by the athlete throughout that period. These metrics analyse workload distribution and intensity changes throughout training sessions or sporting events.

Within scientific research papers exploring training load monitoring or performance analysis in sports, "accumulated acceleration load" and "accumulated acceleration load per minute" are crucial metrics in quantifying and interpreting the physical demands placed on athletes during training and game sessions [3, 5, 7].

2. METHODS

To conduct this research, a comprehensive and detailed descriptive case study was implemented. The study revolved around a highly skilled female volleyball athlete who had participated in numerous international competitions during the competition macrocycle of the 2023 season. The principal aim of the case study was to conduct an in-depth investigation of athlete performance and deliver a comprehensive analysis of the volume and intensity of actual game situations. The study also aimed to apply prescriptions for training organisations to enhance overall athletic performance.

2.1. SUBJECTS

The sample population under study consists of the female Serbian volleyball national team, one of the most talented teams in the world. The average age of participants in this study was 26.8 years (±5.35), with an average height of 186.04cm (±6.4) and weight of 74.1kg (±8.1). The study conducted a descriptive analysis of the performance of a national volleyball team comprising 14 highly skilled and experienced players during the 2023 season. The team participated in three international tournaments, specifically the Volleyball Nations League (VNL), the European Championship, and the Olympic Qualifications Tournament. The analysis was based on 23 games played by the team, out of which they won 14 games and lost 9 across all three competitions.

3. RESULTS

Table 1 presents the mean duration of a volleyball match, including warm-up, at 152.15 (±24.66) minutes, with a range from 116.40 to 203.77 minutes. The volleyball players who underwent testing exhibited an average Accumulated Acceleration Load value of 622.40 (±174.19) a.u. It's worth noting that a non-playing player registered the lowest value of 136.20 a.u., while the highest value recorded was 1122.67 a.u.

The data reveals that the players had an average Accumulated Acceleration Load/min value of 4.16 (±0.90) a.u.. Notably, a non-playing player recorded the lowest value of 1.30 a.u., while the highest value observed was 6.29 a.u. Based on the data presented in Table 1, it can be inferred that the average Acceleration Load per minute was 0.69 (±0.15) acc/min. Notably, the lowest recorded value was 0.22 acc/min, while the highest was 1.05 acc/min. These findings provide valuable insights into the acceleration load trends of the studied subject and can be used to inform future research and analysis.

Table 1. Descriptive data for all variables.

	Duration (min)	Accumulated Acceleration Load (a.u.)	Accumulated Acceleration Load/ min (a.u.)	Acceleration Load/ min (acc/min)	Acceleration Load (max.) (m/s^2)
MIN	116,40	136,20	1,30	0,22	3,26
MAX	203,77	1122,67	6,29	1,05	8,94
AVR	152,16	622,40	4,16	0,69	6,44
SD	24,66	174,19	0,90	0,15	0,96
%cV	16,2	28,0	21,7	21,7	14,9

Throughout the research, the average maximal acceleration observed was 6.44 (±0.96) m/s^2, with a range that extended from a minimum value of 3.26 m/s^2 to a maximum value of 8.94 m/s^2.

4. DISCUSSION

The average length of matches in analysed competitions was 152.15 (±24.66) minutes. Moreover, the training sessions focused on achieving technical-tactical tasks typically span over 2 hours and 30 minutes, following a similar pattern. It is important to note that in some cases, a game, including the warm-up period, can last up to 3 hours and 23 minutes. This must be considered when planning for high volumes and intensity in training, aiming at the worst-case scenarios.

The study found that volleyball players exhibited an average Accumulated Acceleration Load value of 622.40 a.u., with a notable variation in values across participants. After analysing the data, we can make use of the findings to enhance the organisation of training sessions. This is an effective approach to monitoring the training volume during a single season and games, incorporating these findings into the overall monitoring of the training process. By keeping a close eye on the training volume, we can ensure that the sessions are structured to yield maximum benefits. Alternatively, we can average the data to obtain a more comprehensive understanding of the trends. This information enables us to make informed decisions about utilising upcoming microcycles, leading to more efficient and productive training sessions. We analysed the data and found that the maximum Accumulated Acceleration Load obtained was 1122.67 a.u. We can effectively anticipate the worst-case scenario. This means we can plan and schedule peak training in the weekly programs or peak developmental microcycles. This approach ensures that we are prepared for any potential challenges and have optimised our training strategy to achieve the best possible results. Being practical and strategic can maximise our potential and achieve our goals.

The analysis of our game sessions was conducted using the Accumulated Acceleration Load per minute (a.u.). The resulting average value was found to be 4.16 a.u. This data provides valuable insights into monitoring and organising the intensity of our training. With this information, we can ensure that our training sessions are optimised to achieve the desired results while minimising the risk of injuries or other complications.

By closely monitoring the Accumulated Acceleration Load/min value, we can fine-tune our training and make necessary adjustments to achieve the best possible outcomes. To plan our weekly training programs or developmental microcycles efficiently, we should consider the highest value of 6.29 a.u. This will help us anticipate potential challenges and decide to schedule peak training sessions. Additionally, we take a proactive approach to risk management, identifying possible obstacles and developing contingency plans to address them before they become major issues.

The results showed an average Maximal Acceleration of 6.44 m/s^2 during volleyball training, which indicates the dynamic nature of movement patterns and intensity spikes during the activity. This information is crucial in monitoring variables that can indirectly aid in determining neuromuscular fatigue. Additionally, considering Z-scores of individual variabilities can help us to make informed decisions about training prescriptions tailored to each athlete's unique needs. Coaches and trainers can use these variables to create personalised training plans, optimising performance and reducing the risk associated with neuromuscular fatigue.

In addition to the benefits previously mentioned regarding this advanced technology, it's crucial to remember the importance of conducting a critical review of the collected data. To begin, we must establish a standard measurement error for both within a group and within an individual. This measurement will determine the precise amount of change required to be confident that real progress has been made. Also, it is possible to encounter unnaturally high data from the variable “Maximal acceleration” on rare occasions, which cannot be achieved during regular training or gameplay. Such numbers may occur because of a malfunctioning sensor or the sensor being dropped. When such values become a part of a player's or team's averages, it can result in inaccurate data in our monitoring system. This can potentially affect the integrity of our data and impede our ability to make informed decisions based on it. As such, we must address these outliers and ensure they are not incorporated into our data.

To obtain a complete understanding of sports and gameplay, it is crucial to consider data from various tests. These tests include morphological assessments, psychosocial questionnaires, statistical analyses of game efficiency, and evaluations of risk factors related to key performance indicators (KPIs). Incorporating these tests gives us a holistic view of sports and gameplay. It is important to acknowledge that while the technology in question may have certain limitations in its current phase, it remains an integral part of the monitoring process, and all relevant parameters need to be considered when making decisions regarding training and competition.

Advanced technology enables us to achieve greater ecological validity in testing and monitoring. Our understanding of gameplay specificity is enhanced by conducting evaluations in real-life game scenarios and assessing specific movements that are challenging to evaluate outside the court. This improves understanding and connection with conventional field or laboratory testing methods. Also, we are incorporating silent testing procedures that align with players' preferences, as it can be challenging to motivate them to give maximal effort outside of the court. Additionally, this method of monitoring the training process is done daily, unlike designated plan tests during the training micro or mesocycles. It allows us to have valuable data and better statistical analysis.

5. CONCLUSION

Integrating Kinexon IMU technology with Acceleration Load Analysis has revolutionised sports performance analysis in volleyball [2, 4, 3, 5]. Wearable sensors and acceleration metrics allow for real-time data on player movements, leading to improved training strategies, performance optimisation, and injury prevention measures. This technology enables personalised training programs, workload management, and desirable intensity variations. The study emphasises the importance of acceleration-based workload monitoring in athlete development and performance optimisation [1, 5, 9]. Ultimately, this ground-breaking approach to external volleyball monitoring optimises athlete training and performance standards [3, 10]. Coaches and sports scientists can effectively structure training sessions by holding to volume variability and utilising the average data trends. Monitoring Accumulated Acceleration Load per minute values at an average of 4.16 a.u. offers insights into intensity management and training load variability. The average maximal acceleration of 6.44 m/s^2 during volleyball training highlights the dynamic nature of movement patterns, aiding in tracking neuromuscular fatigue. By utilising a data-driven approach, high-performance staff can maximise potential and work towards achieving performance goals efficiently [1, 10].

Future studies in training organisation and management could potentially focus on analysing individual training partitions. Specifically, these studies could entail examining discrete components of a training session or training exercises and classifying these segments based on their relevant volume and intensity. By successfully classifying these distinct portions of training sessions, it may be possible to move closer to a periodisation approach based on descriptive data. Additionally, such an approach could facilitate the utilisation of an agile methodology in the planning and programming of athletic training regimens [11]. Achieving optimal performance during competition or specific events of interest requires precise team planning. By applying an Agile approach to and intermit planning progression [11], teams can effectively reach the best possible form during the competition macrocycle or specificity for events of interest. Such planning requires a high level of expertise, professionalism, and critical thought, and it is crucial to any team's success. Therefore, teams must ensure they plan their macrocycle or specificity with utmost precision and attention to detail to achieve optimal performance during competition.

The integration of wireless sensors provides an opportunity to gain a broad understanding of the volume and intensity of physical activity undertaken by players, both in terms of their internal monitoring through heart rate sensors and external monitoring using Kinexon IMU. The combination of these two metrics is particularly useful in providing insights into players' psychological and physiological states during gameplay or training. Furthermore, by incorporating subjective scaling of training or game effort through the RPE (rate of perceived excitation) questionnaire, a more holistic approach to evaluating players' readiness can be achieved, thereby facilitating better decision-making related to the training process.

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