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GPS technology utilization and athletic performance in university student-athletes

Utilización de la tecnología GPS y el rendimiento atlético en estudiantes-atletas universitarios

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Abstract

Global Positioning System (GPS) technology has become an important tool in sports training for monitoring performance and supporting evidence-based decision-making. This study examined the utilization of GPS technology in sports training and its relationship with athletic performance outcomes among university student-athletes, with emphasis on the mediating role of GPS-derived training load indicators. A quantitative, descriptive–correlational design with mediation analysis was employed. Participants included 75 university student-athletes from five varsity sports who were regularly exposed to GPS-based monitoring during training and competition. Data were gathered using researcher-developed questionnaires on GPS utilization and athletic performance outcomes, complemented by GPS-derived training load indicators. Descriptive statistics, Pearson correlation, and regression-based mediation analysis were used. Results showed that GPS technology was utilized to a very great extent, and athletic performance outcomes were rated at a very high level. A significant positive relationship was found between GPS technology utilization and athletic performance outcomes. However, GPS-derived training load indicators did not significantly mediate this relationship. Based on the findings, an enhancement framework was proposed emphasizing structured GPS utilization, data interpretation, and informed training management. The study concludes that effective integration of GPS technology supports athletic performance among university student-athletes.

Keywords: GPS technology, sports training, athletic performance, training load, university student-athletes

Summary

La tecnología del Sistema de Posicionamiento Global (GPS) se ha convertido en una herramienta importante en el entrenamiento deportivo para el monitoreo del rendimiento y el apoyo a la toma de decisiones basada en evidencia. Este estudio examinó la utilización de la tecnología GPS en el entrenamiento deportivo y su relación con los resultados del rendimiento atlético entre estudiantes-atletas universitarios, con énfasis en el papel mediador de los indicadores de carga de entrenamiento derivados del GPS. Se empleó un diseño cuantitativo, descriptivo–correlacional con análisis de mediación. Los participantes fueron 75 estudiantes-atletas universitarios de cinco deportes de equipo, expuestos regularmente al monitoreo mediante GPS durante el entrenamiento y la competencia. Los datos se recopilaron mediante cuestionarios elaborados por el investigador sobre la utilización del GPS y los resultados del rendimiento atlético, complementados con indicadores de carga de entrenamiento derivados del GPS. Se utilizaron estadísticas descriptivas, correlación de Pearson y análisis de mediación basado en regresión. Los resultados mostraron que la tecnología GPS se utiliza en muy gran medida y que los resultados del rendimiento atlético alcanzaron un nivel muy alto. Se encontró una relación positiva significativa entre la utilización de la tecnología GPS y el rendimiento atlético. Sin embargo, los indicadores de carga de entrenamiento derivados del GPS no mediaron significativamente esta relación. Con base en los hallazgos, se propuso un marco de mejora que enfatiza la utilización estructurada del GPS, la interpretación de datos y la gestión informada del entrenamiento.

Keywords: tecnología GPS, entrenamiento deportivo, rendimiento atlético, carga de entrenamiento, estudiantes-atletas universitarios



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Introduction

Technology integration has transformed contemporary sports training by enabling data-driven monitoring and evaluation of athletic performance. Among the most widely adopted tools is the Global Positioning System (GPS), which allows real-time tracking of athletes' movement patterns and external workload during training and competition (Ma, 2024; Wijaya et al., 2024). Its increasing use reflects the growing emphasis on evidence-based approaches to athlete development, performance optimization, and injury prevention in university sports programs (Midoglu et al., 2024).

GPS technology enables the quantification of external training load variables such as distance covered, high-speed running, accelerations, and decelerations, providing objective information to support training prescription, recovery, and competition preparation (Lally & Finlay, 2024; Palacio et al., 2024). Although GPS-based monitoring is well established in elite sports, its systematic utilization in university sports settings remains insufficiently documented (Kanwal et al., 2025; Rajšp et al., 2025).

Athletic performance is a multidimensional construct influenced by physical readiness, technical execution, tactical awareness, and sustained training adaptation (Pachaiappan et al., 2025). Training load management has been identified as a key factor in optimizing performance and reducing injury risk, with GPS-derived indicators providing valuable insight into athletes' responses to training and competition demands (Huang & Tang, 2024; Long et al., 2022; Ferraz et al., 2023).

Despite extensive international research on GPS technology, empirical studies focusing on university student-athletes remain limited, particularly in developing countries. In these settings, the effectiveness of GPS technology depends not only on its availability but also on how coaches and sports programs interpret and apply performance data (Havanecz et al., 2025; McClean et al., 2024; Metsoyan & Poghosyan, 2023).

Emerging literature further suggests that training load indicators may mediate the relationship between technology utilization and athletic performance. Performance improvements depend on how GPS-derived data are integrated into training plans and aligned with athletes' physical capacities, yet mediation-based studies in university sports contexts remain scarce (Dawson et al., 2024; Teixeira et al., 2021).



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Addressing these gaps, the present study examined GPS technology utilization in sports training and its relationship with athletic performance outcomes among university student-athletes, with GPS-derived training load indicators tested as a mediating variable. The findings aim to contribute empirical evidence to sports science literature and inform evidence-based performance monitoring and training management practices in university sports programs.

Technology Integration in Sports Training and Performance Monitoring

Technology integration has reshaped sports training by enabling evidence-based, data-driven monitoring and evaluation. Digital tools, wearable sensors, and performance analytics allow coaches to plan and adjust training with greater precision than traditional observational methods (Metsoyan & Poghosyan, 2023; Lally & Finlay, 2024). Performance monitoring technologies objectively quantify physical demands, workload, and athlete readiness, supporting informed decisions related to training prescription, recovery, and competition preparation (Palacio et al., 2024; Suyudi, 2023).

However, effective technology integration depends on coaches' capacity to interpret and apply data meaningfully. Access to advanced tools alone does not ensure performance improvement, emphasizing the importance of systematic and informed utilization within specific training contexts (Lifson et al., 2025; Brewer et al., 2025). Although technology adoption is widespread in elite sport, implementation varies across university programs due to differences in resources, institutional support, and coaching expertise (Ren et al., 2025; Putra & Bepa, 2025), highlighting the need for empirical investigation in higher education sports settings.

Global Positioning System (GPS) Technology Utilization in Sports

Global Positioning System (GPS) technology is widely used to monitor athletes' movement patterns and external workload during training and competition. Adapted from navigation systems, GPS provides objective, real-time data on distance, velocity, accelerations, and decelerations, enabling more accurate assessment of physical demands than observational approaches (Wijaya et al., 2024; Schmidt et al., 2023).



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GPS adoption has expanded across team and field-based sports, with studies confirming its validity and reliability for measuring external load in training and competition contexts (Ma, 2024; Midoglu et al., 2024). Effective utilization extends beyond data collection and involves integrating GPS-derived metrics into training decisions, particularly for regulating intensity, workload progression, and athlete responses to training stimuli (Rajšp et al., 2025). Nevertheless, implementation varies across sports programs due to differences in resources, coaching expertise, and organizational support (Zabaloy et al., 2023), especially within university sports environments.

GPS-Derived Training Load Indicators in Sports Training

Training load monitoring is a fundamental component of sports science, providing insight into the physical demands imposed on athletes. Training load is commonly classified into internal and external components, with external load representing the objective physical work performed and quantified using GPS technology (Zanetti et al., 2022; Macedo et al., 2024; Malone et al., 2021).

GPS-derived indicators, including total distance, high-speed running, accelerations, and decelerations, support assessment of training intensity, volume, and movement demands across training and competition (Wijaya et al., 2024). Proper management of these indicators is essential for performance optimization and injury prevention, as inappropriate workload progression may lead to fatigue, overtraining, and increased injury risk (Kanwal et al., 2025; Banković et al., 2024). GPS-based metrics also assist in monitoring athlete readiness and recovery, particularly during congested schedules (Ferraz et al., 2023; Dawson et al., 2024). However, meaningful application requires contextual interpretation based on sport-specific demands, competitive level, and individual athlete characteristics (Long et al., 2022).

Athletic Performance Outcomes in Competitive Sports

Athletic performance is a multidimensional construct encompassing physical, technical, and tactical capacities demonstrated in training and competition. Beyond

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competition results, performance includes indicators of training efficiency, physical readiness, and performance consistency (Sansone et al., 2024; Malone et al., 2021).

Performance outcomes are assessed through both training and competition indicators. Training measures reflect physical and task-related improvements, while competitive outcomes indicate the transfer of training adaptations to performance settings (Metsoyan & Poghosyan, 2023). Physical readiness and match fitness are central components influencing performance stability, particularly in sports requiring repeated high-intensity actions (Malone et al., 2021; Soriotulla, 2025). In university sports contexts, performance evaluation is further complicated by academic demands and variable training exposure (Midoglu et al., 2024).

Relationship Between GPS Technology Utilization, Training Load Indicators, and Athletic Performance

Research increasingly examines the relationship among GPS technology utilization, training load management, and athletic performance. Systematic GPS use provides objective insights into external workload, supporting informed training prescription and performance optimization (Metsoyan & Poghosyan, 2023; Ravé et al., 2020). Positive associations between GPS utilization and performance outcomes have been reported, particularly in training efficiency and physical readiness (Midoglu et al., 2024), although benefits depend on appropriate data interpretation and application (Lifson et al., 2025).

GPS-derived training load indicators are proposed as mechanisms linking technology utilization and performance. Effective load management promotes performance adaptations and reduces injury risk through balanced workload progression and recovery (Kanwal et al., 2025; Wang, 2025; Teixeira et al., 2021; Ferraz et al., 2023). However, mixed findings regarding direct associations between load indicators and performance suggest that training load may function more effectively as a mediating variable rather than a sole predictor (Bridgeman et al., 2021).

Empirical evidence examining these interrelationships in university sports settings remains limited, as most studies focus on elite or professional athletes. Resource variability and contextual differences may influence how GPS data are translated into



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performance outcomes. Addressing this gap, the present study examines the relationship between GPS technology utilization and athletic performance outcomes, with GPS-derived training load indicators serving as a mediating variable among university student-athletes.

Synthesis

The reviewed literature highlights the growing integration of technology in sports training, emphasizing its role in enhancing performance monitoring and supporting evidence-based coaching practices. Technological tools have enabled systematic assessment of athletes' physical demands, allowing for more informed training and performance management decisions. Among these technologies, Global Positioning System (GPS) devices have emerged as reliable tools for quantifying external workload and movement patterns in various sports contexts.

Studies have consistently demonstrated the value of GPS technology in monitoring training and competition demands through objective indicators such as distance covered, speed, and acceleration. However, the effectiveness of GPS technology is largely dependent on the extent to which it is utilized and integrated into training processes, rather than on its mere availability. GPS-derived training load indicators play a critical role in managing workload progression, optimizing physical readiness, and reducing injury risk, thereby supporting sustained athletic performance.

Athletic performance outcomes are influenced by multiple factors, including training efficiency, competition demands, and physical readiness. The literature underscores the importance of systematic training load management in achieving consistent performance outcomes. While existing research suggests positive associations between GPS utilization, training load monitoring, and performance, findings remain inconsistent, particularly regarding the direct impact of training load indicators on performance outcomes.

Notably, most empirical studies have focused on elite and professional athletes, with limited attention given to university student-athletes, especially within developing country contexts. Moreover, few studies have employed mediation models to examine how GPS-derived training load indicators influence the relationship between technology



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utilization and athletic performance. This gap in the literature underscores the need for further investigation into the mediating role of training load indicators in university sports settings. Addressing this gap, the present study seeks to provide empirical evidence on the relationship between GPS technology utilization and athletic performance outcomes, with training load indicators serving as a mediating variable among university student-athletes.

Methods

Research Design

The study employed a quantitative, descriptive–correlational design with mediation analysis to examine GPS technology utilization in sports training and its relationship with athletic performance outcomes among university student-athletes. A cross-sectional approach was used, with data collected at a single point in time to describe GPS utilization, training load indicators, and performance outcomes and to examine their statistical relationships without manipulating study conditions.

Mediation analysis was conducted to determine whether GPS-derived training load indicators mediated the relationship between GPS technology utilization (independent variable) and athletic performance outcomes (dependent variable), allowing examination of both direct and indirect effects.

Participants, Sampling Technique, and Sample Size

Participants were 75 university student-athletes enrolled in a higher education institution implementing GPS-based performance monitoring during training and competition. A purposive sampling technique was used to include athletes with regular training attendance, competition participation, and consistent exposure to GPS monitoring.

The sample included male and female athletes from five sports: men's basketball (n = 15), men's volleyball (n = 15), women's volleyball (n = 15), softball (n = 15), and baseball (n = 15). The sample size was sufficient for descriptive, correlational, and regression-based mediation analyses.



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Instruments

Data were collected using researcher-developed questionnaires and GPS-derived training load records. The GPS utilization questionnaire measured the extent of GPS use in training load monitoring, movement and distance tracking, speed and acceleration analysis, and injury risk and recovery monitoring using a Likert-type scale. The instrument underwent expert validation and pilot testing, yielding acceptable internal consistency.

GPS-derived training load indicators included objective external workload measures such as total distance, movement intensity, speed distribution, and accelerations and decelerations recorded during training and competition. Athletic performance outcomes were assessed using a structured questionnaire covering training performance, competitive performance, and physical readiness and match fitness. This instrument was also validated and pilot-tested.

Data Analysis

Descriptive statistics (frequency, percentage, mean, and standard deviation) were used to summarize respondent profiles, GPS utilization, and athletic performance outcomes. Pearson correlation analysis examined the relationship between GPS technology utilization and athletic performance outcomes.

A regression-based mediation analysis tested the direct effect of GPS technology utilization on performance outcomes, its effect on training load indicators, and the indirect effect through training load indicators. Assumptions of normality and linearity were examined prior to inferential analyses. Statistical significance was set at $\alpha = 0.05$, and all analyses were conducted using standard statistical software.

Ethical Statement

Ethical approval was obtained from the appropriate university authorities. Participation was voluntary, and informed consent was secured from all respondents. Confidentiality and anonymity were maintained, with no personal identifiers included in the data. GPS-derived data were used solely for research and performance monitoring purposes, ensuring the protection of participants' rights and welfare.



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Results

This section presents the study findings on GPS technology utilization in sports training and its relationship with athletic performance outcomes among university student-athletes. Results are organized according to the research questions and include respondent profiles, levels of GPS utilization and athletic performance, the relationship between GPS utilization and performance outcomes, and the mediating role of GPS-derived training load indicators. Findings are presented descriptively and statistically, with interpretation provided in the Discussion section.

Profile of the Student-Athletes

This section presents the profile of the student-athletes who participated in the study on the utilization of Global Positioning System (GPS) technology in sports training. The respondents were described in terms of age, sex, academic program, type of sport, years of athletic participation, and weekly training frequency, providing a general overview of their demographic and sport-related characteristics.

Table 1. *Profile of the Student-Athletes (n = 75)*

Profile Variable	Category	Frequency	Percentage
Age	18–20 years	28	37.33
	21–23 years	39	52.00
	24 years and above	8	10.67
Sex	Male	45	60.00
	Female	30	40.00
Academic Program	Undergraduate programs	75	100.00
Type of Sport	Basketball (Men)	15	20.00
	Volleyball (Men)	15	20.00
	Volleyball (Women)	15	20.00
	Softball	15	20.00
	Baseball	15	20.00
Years of Athletic Participation	1–3 years	22	29.33
	4–6 years	38	50.67
	7 years and above	15	20.00
Weekly Training Frequency	3–4 sessions	18	24.00
	5–6 sessions	41	54.67
	7 sessions and above	16	21.33

As shown in Table 1, most student-athletes were aged 21–23 years (52.00%), followed by those aged 18–20 years (37.33%), reflecting the typical age of university



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varsity athletes. The sample was predominantly male (60.00%), with 40.00% female, and all respondents were enrolled in undergraduate programs.

Participants were equally distributed across five sports—men's basketball, men's volleyball, women's volleyball, softball, and baseball—with 15 athletes (20.00%) per sport, ensuring balanced representation. Most respondents reported 4–6 years of athletic experience (50.67%) and trained 5–6 times per week (54.67%), indicating substantial training exposure appropriate for GPS-based monitoring.

Overall, the respondent profile reflects active and experienced university student-athletes suitable for examining GPS utilization, training load indicators, and athletic performance outcomes.

Extent of GPS Technology Utilization in Sports Training

This section presents the respondents' assessment of GPS technology utilization in sports training and competition. Utilization was evaluated across four dimensions—training load monitoring, movement and distance tracking, speed and acceleration analysis, and injury risk and recovery monitoring—using a four-point Likert scale ranging from Low Extent (1.00–1.75) to Very Great Extent (3.26–4.00).

Table 2. *Extent of GPS Technology Utilization in Sports Training*

Dimensions	Mean	Verbal Interpretation	Rank
Training Load Monitoring	3.52	Very Great Extent	1
Movement and Distance Tracking	3.47	Very Great Extent	2
Speed and Acceleration Analysis	3.39	Very Great Extent	3
Injury Risk Indicators and Recovery Monitoring	3.28	Very Great Extent	4
Composite Mean	3.42	Very Great Extent	

As shown in Table 2, GPS technology utilization in sports training obtained a composite mean of 3.42, interpreted as Very Great Extent, indicating extensive integration into university sports training and competition.

Among the dimensions, training load monitoring ranked highest ($M = 3.52$), followed by movement and distance tracking ($M = 3.47$) and speed and acceleration analysis ($M = 3.39$). Injury risk indicators and recovery monitoring ranked lowest ($M =$



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3.28) but remained within the Very Great Extent category, suggesting consistent, though comparatively less emphasized, application.

Overall, the results indicate that GPS technology is highly utilized in university sports programs, supporting systematic training load management and evidence-based performance monitoring.

Level of Athletic Performance Outcomes

This section presents the respondents' assessment of athletic performance outcomes among university student-athletes. Performance was evaluated across three dimensions—training performance indicators, competitive performance outcomes, and physical readiness and match fitness—using a four-point Likert scale ranging from Low Level (1.00–1.75) to Very High Level (3.26–4.00).

Table 3. *Level of Athletic Performance Outcome*

Dimensions	Mean	Verbal Interpretation	Rank
Training Performance Indicators	3.49	Very High Level	1
Physical Readiness and Match Fitness	3.44	Very High Level	2
Competitive Performance Outcomes	3.37	Very High Level	3
Composite Mean	3.43	Very High Level	

As shown in Table 3, athletic performance outcomes obtained a composite mean of 3.43, interpreted as a Very High Level, indicating strong performance across training, competition, and physical readiness domains.

Among the dimensions, training performance indicators ranked highest ($M = 3.49$), followed by physical readiness and match fitness ($M = 3.44$). Competitive performance outcomes ranked lowest ($M = 3.37$) but remained within the Very High Level category, indicating effective transfer of training gains to competition.

Overall, the results show that university student-athletes demonstrated a very high level of athletic performance, supporting further analysis of its relationship with GPS technology utilization and training load indicators.

Relationship between GPS Technology Utilization and Athletic Performance Outcomes

This section presents the results of the correlation analysis examining the relationship between GPS technology utilization and athletic performance outcomes among university student-athletes using the Pearson product–moment correlation.



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Table 4. *Relationship between GPS Technology Utilization and Athletic Performance Outcomes*

Variables	r-value	p-value	Interpretation
GPS Technology Utilization and Athletic Performance Outcomes	0.68	0.000	Significant Relationship

As shown in Table 4, the correlation analysis revealed a significant positive relationship between GPS technology utilization and athletic performance outcomes ($r = 0.68$, $p < 0.05$). This result indicates that higher levels of GPS technology utilization are associated with higher levels of athletic performance outcomes among university student-athletes.

The positive direction of the correlation suggests that as the extent of GPS utilization in sports training increases, improvements in athletic performance outcomes are also observed. The obtained correlation coefficient reflects a moderate to strong association between the two variables.

Overall, the findings provide statistical evidence supporting the existence of a significant relationship between GPS technology utilization and athletic performance outcomes, thereby addressing the fourth research question of the study.

Mediating Role of GPS-Derived Training Load Indicators

This section presents the results of the regression-based mediation analysis examining whether GPS-derived training load indicators mediate the relationship between GPS technology utilization and athletic performance outcomes among university student-athletes.

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Table 5. *Mediation Analysis of GPS Technology Utilization, Training Load Indicators, and Athletic Performance Outcomes*

Pathway	β	SE	t-value	p-value	Interpretation
GPS Technology Utilization → Training Load Indicators	0.61	0.09	6.78	0.000	Significant
Training Load Indicators → Athletic Performance Outcomes	0.19	0.11	1.73	0.087	Not Significant
GPS Technology Utilization → Athletic Performance Outcomes (Direct Effect)	0.57	0.10	5.70	0.000	Significant
GPS Technology Utilization → Athletic Performance Outcomes (Indirect Effect via Training Load)	0.12	—	—	0.091	Not Significant

As shown in Table 5, GPS technology utilization significantly predicted training load indicators ($\beta = 0.61$, $p < 0.05$), indicating that higher levels of GPS utilization were associated with greater monitoring and management of training load. However, training load indicators did not significantly predict athletic performance outcomes ($\beta = 0.19$, $p > 0.05$).

The direct effect of GPS technology utilization on athletic performance outcomes remained significant ($\beta = 0.57$, $p < 0.05$), while the indirect effect through training load indicators was not statistically significant ($\beta = 0.12$, $p > 0.05$). These results indicate that GPS-derived training load indicators did not significantly mediate the relationship between GPS technology utilization and athletic performance outcomes.

Overall, the findings suggest that while GPS technology utilization has a direct influence on athletic performance outcomes, its effect is not transmitted through training load indicators in the present sample of university student-athletes. This result addresses the fifth research question of the study.

Discussion

This study examined GPS technology utilization in sports training and its relationship with athletic performance outcomes among university student-athletes, with emphasis on the mediating role of GPS-derived training load indicators. The respondent profile indicates adequate age, training experience, and regular participation, supporting the suitability of the sample for performance monitoring research (Kadhim et al., 2024).

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Results showed that GPS technology was utilized to a very great extent, particularly for training load monitoring, movement and distance tracking, and speed and acceleration analysis. This supports previous findings identifying GPS as a key tool for quantifying external workload and guiding evidence-based training decisions (Wijaya et al., 2024; Metsoyan & Poghosyan, 2023). The lower emphasis on injury risk and recovery monitoring suggests the need for further development of preventive applications in university sports settings.

Athletic performance outcomes were rated at a very high level, especially in training performance and physical readiness. Consistent with prior research, structured training supported by monitoring technologies is associated with improved preparedness and performance consistency (Lally & Finlay, 2024; Ren et al., 2025). Competitive performance, while still high, may be influenced by technical, tactical, and psychological factors beyond physical monitoring alone.

A significant positive relationship was found between GPS technology utilization and athletic performance outcomes, reinforcing the role of GPS as a performance-support tool when systematically integrated into training processes (Ma, 2024; Dawson et al., 2024). However, GPS-derived training load indicators did not significantly mediate this relationship. Although GPS utilization predicted training load indicators, these indicators did not directly predict performance, suggesting that performance outcomes are shaped by multiple interacting factors beyond workload metrics (Zanetti et al., 2022; Sašek et al., 2024).

Overall, the findings indicate that GPS technology utilization is directly associated with athletic performance outcomes, highlighting the importance of effective data interpretation, coaching expertise, and integrated monitoring practices. These results support the development of an enhancement framework emphasizing structured GPS utilization and evidence-based training management in university sports programs.

Proposed Enhancement Framework for Optimizing GPS Technology Utilization

This section presents the proposed enhancement framework developed from the study findings on GPS technology utilization and athletic performance outcomes among university student-athletes, addressing the sixth research question and grounded in the study's empirical results.



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Table 6. *Proposed Enhancement Framework for Optimizing GPS Technology Utilization in Sports Training*

Framework Component	Description	Role in Performance Optimization
GPS Technology Utilization	Systematic use of GPS technology for training load monitoring, movement and distance tracking, speed and acceleration analysis, and injury risk indicators and recovery monitoring.	Provides objective data on athletes' physical demands during training and competition.
Data Processing and Interpretation	Contextual analysis and interpretation of GPS-derived data by coaches and sports science staff.	Transforms raw GPS data into meaningful information for training decisions.
Coaching and Training Management Decisions	Adjustment of training intensity, volume, and session design based on interpreted GPS data.	Supports evidence-based planning and appropriate workload management.
Athlete Readiness and Performance Feedback	Continuous monitoring of training performance, physical readiness, and match fitness.	Creates a feedback loop that informs subsequent training modifications.
Athletic Performance Outcomes	Improvements in training efficiency, readiness, and competitive performance.	Represents the intended outcome of optimized GPS technology utilization.

As shown in Table 6, the proposed enhancement framework illustrates how GPS technology utilization contributes to athletic performance outcomes through a structured process. GPS utilization serves as the primary input, generating data on training load, movement patterns, and performance-related variables, which require systematic interpretation by coaches and sports practitioners.

Coaching and training management decisions function as the central mechanism through which GPS-derived data influence athlete readiness and performance feedback, enabling timely adjustments to training programs. This process ultimately supports improved athletic performance outcomes, including enhanced training efficiency, physical readiness, and competitive performance consistency.

Overall, the enhancement framework provides an evidence-informed model for optimizing GPS technology utilization in university sports programs and directly



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addresses the sixth research question by guiding systematic integration of GPS data into training management practices.

Limitations of the study

Despite its strengths, this study has several limitations. First, the cross-sectional design limits causal interpretation of the relationships among GPS technology utilization, training load indicators, and athletic performance; longitudinal studies are recommended.

Second, the use of participants from a single higher education institution may limit the generalizability of the findings to other contexts and competitive levels.

Third, although objective GPS-derived indicators were included, the partial reliance on self-reported measures may introduce response and recall bias.

Fourth, the mediation analysis examined training load indicators as the sole mediator, excluding other factors such as technical, tactical, psychological, and recovery-related variables that may influence performance.

Finally, the sample size ($n = 75$), while sufficient for the analyses conducted, limits sport-specific comparisons. Future studies should include larger and more diverse samples.

Conclusion

This study examined GPS technology utilization in sports training and its relationship with athletic performance outcomes among university student-athletes, with emphasis on the mediating role of GPS-derived training load indicators. Using a quantitative descriptive–correlational design with mediation analysis, the study provides empirical evidence on the role of GPS technology within university sports programs.

Findings showed that GPS technology was utilized to a very great extent, particularly for training load monitoring, movement and distance tracking, and speed and acceleration analysis, indicating its integral role in training management. Athletic performance outcomes were rated at a very high level, especially in training performance and physical readiness, suggesting that structured training supported by monitoring technologies contributes to positive performance outcomes.

A significant positive relationship was established between GPS technology utilization and athletic performance, confirming that systematic GPS integration supports performance enhancement through objective feedback and informed training decisions.



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However, GPS-derived training load indicators did not significantly mediate this relationship, indicating that performance improvements are influenced by broader training management and coaching processes rather than training load metrics alone.

Based on these results, an enhancement framework was proposed to guide evidence-based GPS utilization in university sports programs. The framework emphasizes structured data use, informed interpretation, and integrated coaching decisions to support athlete readiness and performance.

Overall, GPS technology is a valuable resource for enhancing sports training and athletic performance in university settings. Its effectiveness depends not only on data collection but on the systematic interpretation and application of GPS data within a holistic training and performance monitoring framework.

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