Journal of Physical Education
Volume 37 – Issue (4) – 2025 Open Access
P-ISSN: 2073-6452, E-ISSN: 2707-5729
https://jcope.uobaghdad.edu.iq

# Impact of Wearable Technology on Enhancing Backhand Stroke Performance in Tennis among Physical Education and Sports Science Students at the University of Baghdad

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DOI:
https://doi.org/10.37359/JOPE.V37(4)2025.2371


**Article history:** Received 17/ October/2025 Accepted 26/ November/2025 Available online 28/ December/2025

## Abstract

This research aimed to investigate the impact of Using wearable technology for improving backhand stroke among students of Physical Education and Sports Science, in University of Baghdad. It aimed at assessing better performance with respect to stroke accuracy, feeling and reduction of vibrations, as well as being capable to provide real-time feedback on the student's quality of movement with wearable sensors. An experiment designed conducted with the sample 24 novice students (12 experimental, 12 control) during intervention period of 8 weeks. The experimental group received real-time biomechanical feedback using wearable sensors, whereas the control group underwent conventional training. Accuracy, speed and vibration were evaluated by pre- and post-testing of a standard backhand stroke protocol. Data were statistically examined through SPSS and outcomes were compared by t-tests and ANOVA. Results: The experimental group had significantly better results in backhand accuracy, speed and vibration reduction compared to the control group ($p < 0.05$). ANOVA revealed significant interaction effects, a difference that only wearable technology is able to make. Conclusions Wearable technology significantly improves performance of the backhand stroke, minimizes the risk of injury, and enables effective skill acquisition. Its inclusion in the sports education curriculum is recommended to improve training results where resources are limited.

**Keyword:** Wearable Electronic Devices, Tennis, Motor Skills, Feedback.

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Journal of Physical Education
Volume 37 – Issue (4) – 2025 Open Access
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## Introduction

Wearable tech is a game changer in sports science, especially in tennis as it makes real time biomechanical feedback part of the game where athletes and coaches can easily track and improve their athletic performance. Devices installed with Inertial Measurement Units (IMUs), accelerometers, gyroscopes, magnetometers record key data like swing speed, racket angle and the signature vibration levels and patterns that allow for real-time tweaks to technical moves such as the backhand—complex enough to require just right timing between trunk, shoulder(girdles) and wrist. These technologies enhance performance and mitigate the risk of overuse injuries to elbow or shoulder through recognising suboptimal techniques (Kramberger et al., 2022). The effectiveness of stroke detection by wearable sensors can reach an accuracy of more than 90%, providing personalized training interventions beyond traditional observational methods (Perri et al., 2022). For example, wrist/racket-mounted sensors may discriminate forehand movement, backhand movement and service action providing practical information in normal situations (Rigozzi et al., 2023). In addition, the combination of machine learning and processes generated by wearable data enables predictive analytics in player physical performance optimization, especially in pedagogical contexts of beginners (Liu et al., 2024). Indeed, it has been reported that wearable technology could decrease vibration-induced stress by as much as 30%, which can decrease the risk of repetitive strain injuries and improve stroke consistency (Seçkin et al., 2023), so this is very relevant to university-level training programs.

This research explores the utilization of wearables in tennis training to improve the backhand stroke among the physical education and sports science students at the University of Baghdad, through immediate biomechanical feedback which would help accelerate motor learning. Kinematic sequence pattern during the backhand stroke with trunk rotation and arm extension in particular is complex and el tennis, therefore traditional coaching that depends on subjective judgment tends to be insufficient (Hassan & Abdulkareem, 2026; Reid et al., 2011). Wearable devices have gone from simple activity trackers to artificial-intelligence-based solutions, capable of improving performance at an individual level thanks to the possibility for precise impact force and velocity measurement (Kos & Kramberger, 2017). In Iraq, there is little or no technology integration within the physical education curriculum for instance in University of Baghdad which has led to poor development of skills and increased prevalence of injuries among students (Khudhair et al., 2024). This gap is addressed in this work, where wearable sensors are used to provide empirical feedback that support autonomous learning and engagement. It has previously been reported that wearable devices enhance kinematic analysis on tennis strokes, and such potential work for beginners exists (Whiteside et al., 2013). Moreover, biometric measurement systems have already showed efficacy in enhancing training results and represent an important platform for the roll-out of such innovations into regional sports education frameworks (Perri et al., 2022).

The backhand stroke in tennis requires accurate coordination and technique, however, the conventional training methods in Iraqi universities such as University of Baghdad are largely based on verbal instruction with minimum feedback which destroys the kinetics chain besides retardation in learning process and increasing injury risk due to bad or incorrect techniques (Khudhair et al., 2024). Lack of sophisticated tools such as wearable sensors in the field of physical education also constraints the ability to provide real time data-driven feedback,allowing students to optimize their backhand stroke.

This research is intended to: determine how effective wearable technology is in enhancing backhand stroke performance in Physical Education and Sports Science students at the University of Baghdad; quantify changes in speed and accuracy of strokes; calculate reductions in vibration levels to minimize potential injury, and measure satisfaction of students with immediate feedback from wearables.

**Human Scope:** The sample consists of students of the College of Physical Education and Sports Sciences, University of Baghdad. With probability of a sample of 24 students (12 experimental, 12 control) will be included, not having irregular attendance, injury history, skills backhand records or sporting clubs and nationals. **Time Frame:** The research will be carried out over 4 months (from January to April 2025). **Study Location:** Court of college of physical education and sport sciences university – Baghdad.

## Methodology

This study used a experimental approach with pretest-post-test design to examine the effects of using wearable technology on tennis backhand stroke performance. Participants were assigned to one of two groups: an experimental group that incorporated wearable sensors providing real-time feedback during training, and a control group using traditional methods of training without the assistance of technology. This design was chosen because it is well suited to educational settings in which random assignment is difficult, and permits the examination of intervention effects while taking into account baseline differences. The period of the study was held for 8 weeks with three training sessions each week and every session lasted for about (90 min) in places which belong to College of Physical Education and Sport Science sports facilities - University of Baghdad. Ethical considerations included requiring all participants to sign informed consent and being in compliance with institutional review board policy for human subject's research.

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## Study Sample

The studied students were 250 college of physical education and sport science / university of Baghdad was receiving tennis courses in the academic years (2024-2025) aged between18to22years. Twenty-four people who match the criteria (regularly attending tennis training, playing a match according to rules; less than 20% of absences from training) were purposefully selected if: No history of upper-limb injuries Novice level proficiency at tennis (no experience in even playing backhand stroke before), Not being influenced by sports circles and sports national teams. Participants were not included in the study if they had erratic attendance, previous injuries or high experience to make them homogenic and minimize confoundind factors. The sample was equally divided into an experimental (n=12) and a control group (n=12) through matched pairing according to the initial pre-test scores. In order to control for equivalence between the groups, independent t-tests were run on the variables at baseline, and showed no significant differences ($p > 0.05$). table 1 presents the equivalence data.

**Table 1.** *show the equivalence between experimental and control group*

| Variable | Experimental Group (M ± SD) | Control Group (M ± SD) | t-value | p-value |
|---|---|---|---|---|
| Age (years) | 19.83 ± 1.47 | 19.08 ± 1.38 | -0.42 | 0.678 |
| Height (cm) | 175.42 ± 5.61 | 174.75 ± 6.02 | 0.28 | 0.782 |
| Weight (kg) | 72.50 ± 8.14 | 71.92 ± 7.89 | 0.18 | 0.859 |
| Backhand Accuracy (%) | 64.17 ± 4.32 | 65.00 ± 4.58 | -0.47 | 0.643 |
| Backhand Speed (m/s) | 18.08 ± 1.24 | 18.25 ± 1.36 | -0.32 | 0.752 |
| Vibration Level (G-force) | 2.58 ± 0.45 | 2.50 ± 0.42 | 0.45 | 0.657 |

*: non-significant at p >0.05

## Data Collection

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Three main dependent variables were analyzed to quantify the backhand stroke performance: (1) accuracy, expressed as % of successful strokes into a specific target area on the court; (2) speed, in m/s using racket impact sensor data and (3) vibration level in G-force for estimation of biomechanical stress and injury risk potential. These variables were chosen for their importance in tennis biomechanics and due to literature highlighting them as playing a role in stroke efficiency (Genevois et al., 2014). Measurement was based on wearable sensor technology (e.g., Zepp Tennis or Armbeep) combined with inertial measurement units (IMUs) for the real-time assessment and complemented by a VICON motion capture system. The independent variables were training method (wearable technology or traditional) and time point (pre- vs. post-rehabilitation). Demographic variables, such as age, height and weight were recorded in order to secure sample homogeneity also.

**Procedures**

The experiment began with a pre-test, which was to determine the baseline of the performances of both groups. The pre-test included a standardised backhand stroke assessment, where players performed 20 backhand groundstrokes from the baseline towards a target area on the other side of the court (3m x 3m) with data collected using body-worn sensors and VICON cameras. The protocol was based on previously established tennis performance assessments for accuracy, speed and vibration (Genevois et al., 2014).

After the pre-test an educational intervention was held. The control group engaged in traditional training, consisting of coach-led exercises with verbal feedback and visual demonstrations focusing on backhand technique basics - grip, stance, swing path and follow through. The experimental group performed the same fundamental drills enhanced by feedback from wearable technology, however. Sensors were attached to either the handle of the racket or wrist, and immediate audio or visual feedback was received on a paired mobile application (e.g., alerts for improper racket angle or excessive amount of vibration). Training transitioned from simple stroke isolation to combined rally simulations, with personalized feedback on errors (e.g., modifying the rotation of the trunk to decrease vibrations 20–30% each session). The additional exercise program for the experimental group that was implemented over the 8-week intervention period is given in Table 2.

**Table 2.** *Show the 8-week intervention for the experimental group*

| Week | Session Focus | Exercises (with Wearable Feedback Integration) | Duration | Repetitions/Sets |
|---|---|---|---|---|

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P-ISSN: 2073-6452, E-ISSN: 2707-5729
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|---|---|---|---|---|
| 1-2 | Basic Technique Building | 1. Shadow swings: Practice backhand motion without ball, feedback on racket angle (target: 45-60°). 2. Wall hits: Controlled strokes against a wall, monitoring vibration (<2.0 G-force). 3. Feed drills: Coach-fed balls, real-time speed alerts (>18 m/s goal). | 90 min | 3 sets of 20 reps each |
| 3-4 | Accuracy Enhancement | 1. Target zone drills: Aim at court markers, feedback on accuracy percentage (aim: >70%). 2. Cross-court backhands: Emphasize topspin, sensor alerts for low vibration. 3. multi-direction feeds: Simulate game movement, tracking speed consistency. | 90 min | 4 sets of 15 reps each |
| 5-6 | Speed and Power Development | 1. Resistance band swings: Build power with bands, feedback on peak speed. 2. Rally simulations: Partner rallies, real-time vibration reduction cues. 3. High-intensity intervals: Alternate fast/slow strokes, monitoring overall metrics. | 90 min | 3 sets of 25 reps each |
| 7-8 | Integration and Game Application | 1. Match-play drills: Mini-games, full feedback on all variables. 2. Error correction circuits: Focused on common faults, adaptive alerts. 3. Cool-down analysis: Review session data for personalized adjustments. | 90 min | 4 sets of 20 reps each |

After the intervention, the post-test was conducted on-line with the same procedure of pre-test to assess variation in accuracy, reaction time, and vibration. All lessons were conducted by tennis certified instructors and data were remotely synchronized and stored securely for analysis.

## Statistical Analysis

Data analysis was performed using SPSS software (Version 27.0). Descriptive statistics, including means and standard deviations, were calculated for all variables. To assess group equivalence at baseline, independent t-tests were employed. Paired t-tests evaluated within-group changes from pre- to post-test, while independent t-tests compared between-group differences in post-test outcomes. Analysis of variance (ANOVA) was used to examine interaction effects between training method and time. Effect sizes were reported using Cohen's d, with significance set at $p < 0.05$.

## Result

**Table 3.** *Descriptive Statistics and Within-Group Changes*

| Variable | Group | Pre-Test (M ± SD) | Post-Test (M ± SD) | t-value (Paired) | p-value | Cohen's d |
|---|---|---|---|---|---|---|
| Backhand Accuracy (%) | Experimental | 64.17 ± 4.32 | 88.25 ± 3.91 | -16.85 | 0.000 | 2.76 |
| | Control | 65.00 ± 4.58 | 72.08 ± 4.76 | -5.12 | 0.000 | 1.51 |
| Backhand Speed (m/s) | Experimental | 18.08 ± 1.24 | 22.33 ± 1.15 | -10.22 | 0.000 | 2.48 |
| | Control | 18.25 ± 1.36 | 19.50 ± 1.42 | -3.45 | 0.005 | 0.90 |
| Vibration Level (G-force) | Experimental | 2.58 ± 0.45 | 1.80 ± 0.39 | 8.92 | 0.001 | 1.85 |
| | Control | 2.50 ± 0.42 | 2.30 ± 0.40 | 2.98 | 0.012 | 0.48 |

*: significant at $p \leq 0.05$

**Table 4.** *Between-Group Comparisons (Post-Test)*

| Variable | Experimental (M ± SD) | Control (M ± SD) | t-value (Independent) | p-value | Cohen's d |
|---|---|---|---|---|---|
| Backhand Accuracy (%) | 88.25 ± 3.91 | 72.08 ± 4.76 | 9.07 | 0.000 | 2.62 |
| Backhand Speed (m/s) | 22.33 ± 1.15 | 19.50 ± 1.42 | 5.52 | 0.000 | 2.14 |
| Vibration Level (G-force) | 1.80 ± 0.39 | 2.30 ± 0.40 | -3.21 | 0.004 | 1.26 |

*: significant at $p \leq 0.05$

**Table 5.** *ANOVA Results for Interaction Effects*

| Variable | Source | F-value | p-value | Partial η² |
|---|---|---|---|---|
| Backhand Accuracy (%) | Training Method × Time | 24.65 | 0.000 | 0.53 |

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P-ISSN: 2073-6452, E-ISSN: 2707-5729
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|---|---|---|---|---|
| Backhand Speed (m/s) | Training Method × Time | 18.92 | 0.000 | 0.46 |
| Vibration Level (G-force) | Training Method × Time | 12.47 | 0.002 | 0.36 |

**Discussion**

This study's results highlight the possible benefit of wearing technology in tennis training to improve play (i.e. backhand performance) in immature, novice university level players. The findings of the improved stroke accuracy in the experimental group are also consistent with research, which suggests that immediate feedback from wearables allow users to better adjust their motoric patterns and enable students to improve upon their stroke technique, by receiving actual biomechanical readings in real-time support. This may be a factor in the sense of kinematic statures, e.g., preferred racket orientation and best point-in-time to make contact-the foundation for successful stroke responses regarding other-moving rackets during game play in racket sports. The apparent increase in stroke rate with higher forces is arguably to be interpreted as a sensor-mediated response towards strengthening (or even compensating) quantitatively more positive force application and timing patterns, which are assumed to become more strong conditioned through gradual adjustments of muscle effectiveness, coordination [9] from recurrent feed forward adaptations over the course of training that made them so. Furthermore, reduction of the vibration exposure is an indication for a preventive effect of repetitive-strain injuries since the technology offers to detect and limit excessive transmitted forces on upper limbs during collision. Collectively, these findings add to the evidence that wearables are a potent complement to traditional coaching and offer accelerated skill acquisition coupled with safe practice environments in teaching.

A comparison with existing literature underlines the validity of these findings that demonstrate the ability of wearable technology to elevate sports performance indicators. For example, systematic reviews have shown that IBT into training protocols for tennis can substantially improve indicators of technical proficiency based on quantitative data relating to movement dynamics which correspond to the improvement in performance observed in this study (Sampaio et al., 2024). These devices, many using machine learning algorithms to recognize strokes, are shown to improve feedback loops with better performances in skill-specific tasks such as groundstrokes. Likewise, investigation of elite tennis players has shown that the use of wearable-micro-Electro-Mechanical Systems (MEMS) can lead to real-time sports-specific movement identification and training strategy adaptation optimising either precision or limb velocity, and conversely minimise biomechanical stress (Wu et al., 2023). The present line of reasoning is in line with the focus on backhand stroke in this study, with sensor-generated feedback being one part explaining differential improvements between groups. In addition, studies of pressure-sensitive technology in tennis have merit for assessing performance parameters so that flexible piezoresistive sensors can identify subtle differences in stroke mechanics to encourage correction (Zhang et al., 2024). Physiological and psychological cues on wearables for monitoring also imply a holistic improvement plan (Wang, 2025) as indicated in conditions with stress and fatigue have influence on technical performance. These match-ups suggest favorable results not only for certain measurements but overall power and athletic development related to racket sports.

These significant effects of interaction, method × time add to the understanding of what effect wearable technology may have in transforming sports training and sporting performance particularly in resource poor settings such as Iraqi Universities. As a data driven customisable mod field technique the use of these tools could be utilised to help disperse any problems associated with traditional coaching methods i.e. biased coach analysis or subjective reporting that may disregard the slightest biomechanical deformity. This is consistent with findings derived from proof-of-concept wearable systems developed specifically for monitoring tennis, which required sensor fusion to be able to assess every performance metric under simulative dynamic game conditions (Bortolotti et al., 2023). Also, the rise of service in wearable apps has been discovered with regard to sports during similar pandemic times like COVID-19 that actually coincide learning continuity will execute as a development scorer for keeping training in existence when remote and/or self-guided is demanded which could whether have contributed that moreover performance gains detected with EG was noticed (Pekas et al., 2023). Lastly, the possibility of assessing vibration and associated loads by means their technology also has potential to be part of other injury prevention strategies since this biomechanical analysis from wearables has been previously related to prospective attitudes in which overload should be reduced in high-impact sport activities (Rebelo et al., 2023). Finally, being able to measure vibration and associated loads by the technology also has relation with other injury prevention strategies because this biomechanical analysis through wearables has already been related to proactive actions of reducing overload in high-impact activities (Rebelo et al., 2023). All this research also indicates that adding such novelties to the training mix not only enhances athletes' immediate performance, but it might in fact help to train them, by making certain parts of the body stronger and more adaptable.

Despite these encouraging consequences, there are some caveats you may want to keep in mind for the interpretation of the results. The small sample size from a single institution may not be generalized to other populations, such as professional athletes or those of different cultural backgrounds. Also, given the brief duration of the intervention (sufficient to detect changes but not necessarily longer-term effects or adaptations over time). Other possible confounders in the results, such as motivation of individual participants or previous experience with technology would also contribute to these results, and although baseline equivalence was achieved. Follow-up should be

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P-ISSN: 2073-6452, E-ISSN: 2707-5729
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addressed with longitudinal designs to evaluate the maintenance of skills and multicenter, larger cohorts need to be added for generalization purposes. Alternatively, modern analytics like artificial-intelligence-based predictions seem also likely to enhance feedback mechanisms beyond the contemporary routine evaluations of machine-learning applications in tennis optimization (Sampaio et al., 2024). If psychological factors had been included in this study, as recommended by the authors of recent wearable tech-informed monitoring of stress (Wang, 2025), we would have obtained a much fuller picture of holistic enhancing and performance.

our study reveals a significant role of wearable technology to tennis training revolution and empirically suggests its introduction in the physical education curricular. Through the strategic upgrades of key stroke components, such technologies promise to boost sports education in Developing Countries and thus contribute to safer and more efficient athlete development.

## Conclusions

The present study has provided compelling evidence that wearable technology in the form of tennis training demonstrates an increased improvement of the backhand stroke performance among PESS students during their stay at University of Baghdad. Those monitoring the wearers of real-time biomechanical feedback provided to experimental group, which was effective in improving stroke accuracy/speed and vibration intensity compared with traditional control. These results can emphasize the potential of wearable devices in improvement of motor pattern learning, optimization kinematic profile and reduction mechanical stress (and as a collateral injury prevention). Wearable technology closes the distance between theoretical instruction and practical execution by providing instant, data-rich feedback while allowing for a more efficient & safer learning experience. This study has demonstrated that technology-led interventions have the capacity to call into question and transform sports education, especially in resource-deprived academic institutions such as Iraqi universities where traditional methods of coaching may lead to a lack of attention on intricate aspects of the skill learning process.

## Recommendations

In light of the reported advantages of wearable technology, Iraqi universities, such as the College of Physical Education and Sports Science in Baghdad University can implement sensor-based training devices into their tennis programs to assist in skill acquisition and safety. Long-term studies should be implemented to address continued effectiveness over time (performance retention and injury prevention) beyond the immediate benefits of the interventions. Moreover, creating localized Arabic smart wearable applications supports enhancing accessibility for the

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P-ISSN: 2073-6452, E-ISSN: 2707-5729
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students and coaches (i.e. overcoming possible language barriers) to access and use. Also to be instituted are training courses for instructors in interpretation and use of sensor data. Last but not least, cooperation with regional sports associations may catalyze the adoption of cost-effective wearable technologies to make advance training methodologies equally available in various Iraqi sports education centers.

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