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Case Study of Forearm Extensor Activity Across Tennis Strokes as Risk Markers for Tennis Elbow Using a Wearable EMG Device

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Abstract

Lateral epicondylitis, commonly known as tennis elbow, is associated with repetitive forearm movements during tennis. This study investigated differences in recorded forearm muscle activity across three forehand grips and two backhand styles using a custom wireless electromyography (EMG) device. Surface electrodes were positioned over the right extensor carpi radialis brevis (ECRB) region of a single tennis player. A total of 120 candidate strokes were recorded across Eastern, Semi-Western, and Western forehands and one-handed and two-handed backhands. EMG signals were sampled at 500 Hz, transmitted wirelessly, and analyzed using baseline-corrected envelope amplitudes. The Semi-Western forehand produced the highest median recorded amplitude (258.44 units), followed by Western (209.32) and Eastern (189.94). Two-handed backhands showed slightly higher median amplitudes than one-handed backhands (146.55 versus 128.54 units). However, substantial signal clipping, particularly during forehands, limited the reliability of these comparisons. Although the device successfully captured repeated muscle activation patterns during tennis, the findings could not establish differences in injury risk. Future research should improve signal quality and include additional participants to better evaluate the relationship between tennis technique and forearm muscle activity.

Introduction

Tennis is a sport that requires constant repetition of movements that use the wrist and forearm, placing considerable demands on the muscles involved in gripping and swinging a racket. One of the most common injuries associated with these movements is lateral epicondylitis, more commonly known as tennis elbow, which affects the tendons near the outside of the elbow. The extensor carpi radialis brevis (ECRB), a forearm muscle involved in wrist extension and stabilization, is the main muscle involved in this condition. Previous research has investigated forearm muscle activity in tennis players, although the relationship between specific muscle activation patterns and lateral epicondylitis is still unclear (Alizadehkhaiyat & Frostick, 2015).

Electromyography (EMG) provides a possible method of recording electrical activity associated with muscle contractions. By placing electrodes on the skin above the target muscle, researchers can observe muscle activation during movement, and establish patterns. EMG has been used to investigate the muscular demands of different tennis strokes, including forehand grips and backhand techniques. However, recorded EMG amplitude does not directly measure muscle force or tendon strain, and its interpretation is limited by factors such as electrode placement, signal processing, and measurement quality.

Previous studies have shown that tennis technique can impact forearm muscle activity. Differences in activation patterns have been observed among players using Eastern, Semi-Western, and Western forehand grips, with some forearm muscles exhibiting greater activation among Eastern-grip players (Stepnik & Jones, 2023).

Research comparing Eastern and Western forehands has also observed differences in muscle activity and impact-load attenuation (Dong et al., 2024). Additionally, differences in the activation of specific forearm muscles have been observed between one-handed and two-handed backhand strokes (Giangarra et al., 1993). These findings suggest that variations in tennis technique may have an influence on muscular demands, although they do not guarantee that any particular technique causes injury.

Despite existing research, accurately comparing forearm muscle activity during tennis still has its challenges. Previous reviews have found inconsistencies in methodology and insufficient evidence to conclusively link certain EMG patterns to tennis elbow (Alizadehkhaiyat & Frostick, 2015). Furthermore, interpreting EMG amplitude requires consideration of signal quality and the limitations of the recording equipment. These challenges are especially relevant when using wearable devices to collect measurements during play.

This study investigated whether a wireless EMG device could record and distinguish patterns of right-forearm muscle activity across three forehand grips (Eastern, Semi-Western, and Western) and two backhand styles (one-handed and two-handed). EMG recordings were collected during repeated strokes from a ball machine, and baseline-corrected envelope amplitudes were compared across conditions. It was hypothesized that if different forehand grips and backhand styles place different demands on the forearm muscles, then the recorded EMG activation will vary across the five tennis stroke conditions. The study also evaluated signal reliability and saturation to determine the limitations of using an EMG system for tennis biomechanics research.

Materials and Methods

1. Study Design

This study compared forearm muscle activity across five tennis stroke conditions: Eastern, Semi-Western, and Western forehands, and one-handed and two-handed backhands. The participant was a right-handed tennis player with experience in both backhand styles. Two trials of recordings were collected per forehand grip and three per backhand style, with ten strokes each, making for a total of 120 strokes across 12 recordings.

2. Equipment and Electrode Placement

A custom wireless EMG device was built using a NodeMCU ESP8266 microcontroller and an analog EMG sensor of unknown model. The EMG sensor was powered by two 9V batteries, while the microcontroller used an external USB power bank. EMG signals were sampled at a frequency of 500 Hz and transmitted wirelessly to a Python program, which saved the data as CSV files.

Before testing, the skin was cleaned with rubbing alcohol. Recording electrodes were placed over the extensor carpi radialis brevis (ECRB) region of the right forearm, with the reference electrode near the lateral epicondyle of the humerus. Electrode placement and sensor settings remained unchanged throughout testing.

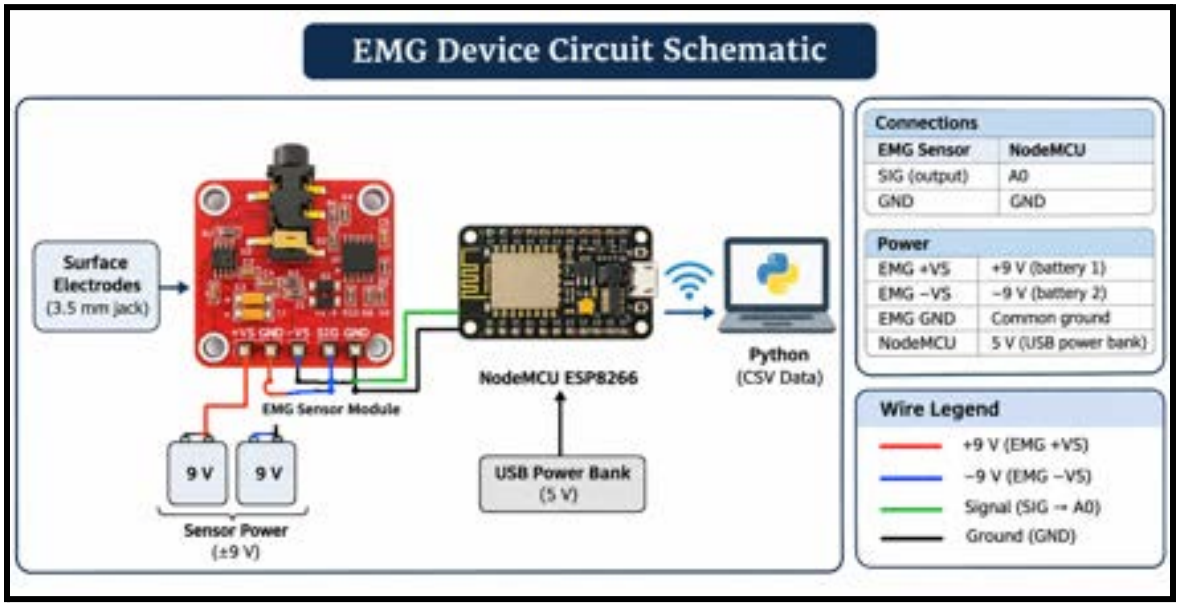


Figure 1. Simplified EMG Sensor Circuit Diagram.

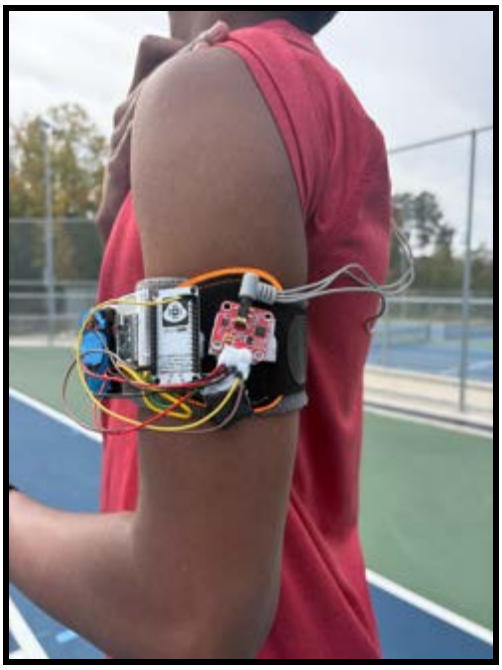


Figure 2. Wearable EMG Device Positioned on the Right Arm.

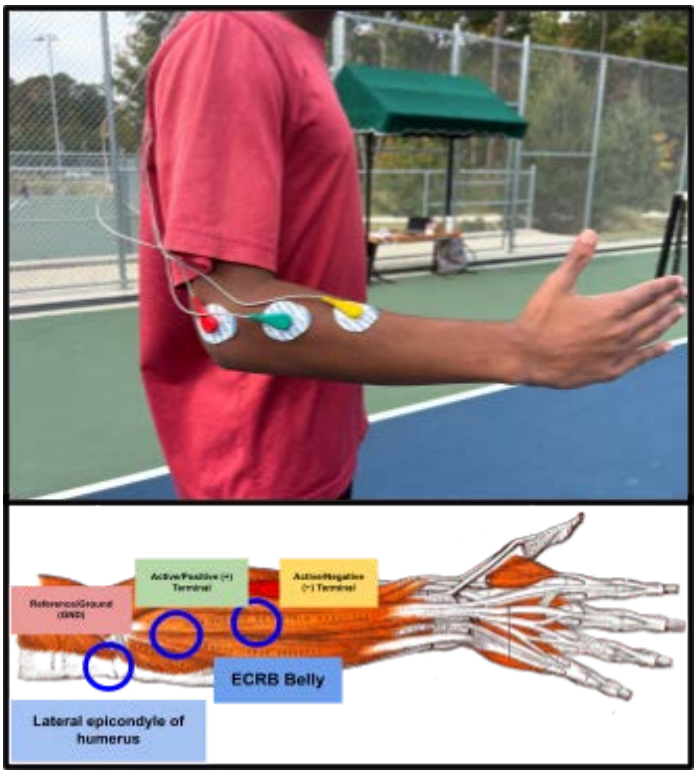


Figure 3. Electrode placement over the right forearm: (a) actual electrode placement during data collection; (b) anatomical illustration of the ECRB region. Anatomical illustration by Henry Vandyke Carter, from Gray's Anatomy (1918), modified by Helgo13 (2019), via Wikimedia Commons. Public domain. Modified by author.

3. Data Collection

A ball machine delivered ten shots per recording at approximately eight-second intervals. Forehand recordings were organized into two rounds containing all three grips, with 30 seconds between grips and one minute between rounds. The ball machine's settings remained unchanged, although their exact values were not recorded.

Recordings affected by interruptions, inconsistent strokes, or substantial data loss were repeated when possible. The original first two-handed backhand recording was replaced because of excessive sample loss.

4. Data Analysis

EMG recordings were processed using Python. The envelope signal was smoothed using a centered 125-sample rolling average. An automated algorithm identified ten prominent activation peaks per recording, separated by at least five seconds.

Each peak was analyzed within a two-second window extending 0.75 seconds before and 1.25 seconds after the peak. Baseline activity was estimated from the median envelope amplitude between 3.5 and 2 seconds before each peak. Baseline-corrected mean amplitude was calculated by subtracting this value and averaging the nonnegative differences within the stroke window.

Sample loss was estimated from missing sample numbers, while signal clipping was defined as raw ADC readings at or above 1020. Median activation, interquartile range (IQR), and clipping percentages were calculated for each condition. Results were compared descriptively without inferential statistical testing.

Results

1. Data Collection and Signal Reliability

EMG recordings were collected from the right forearm during five tennis stroke conditions: Eastern, Semi-Western, and Western forehands, and one-handed and two-handed backhands. The dataset consisted of 12 trials containing 10 strokes each, totaling 120 candidate strokes.

An automated algorithm identified activation events using major EMG envelope peaks. Each event was analyzed within a two-second window, extending 0.75 seconds before and 1.25 seconds after the peak. Baseline-corrected mean envelope amplitude was calculated to estimate recorded activation.

Wireless transmission was generally consistent, with 11 of the 12 original recordings showing sample loss below 0.1%. The original first two-handed backhand recording was excluded due to 9.86% sample loss and replaced with a recording showing 2.04% loss. Signal clipping was defined as raw ADC readings at or above 1020, near the device's upper measurement limit.

2. Forehand Grip Comparison

Twenty candidate strokes were analyzed per forehand grip. The Semi-Western grip showed the highest median recorded activation (258.44 envelope units), followed by Western (209.32) and Eastern (189.94).

Forehand grip	Strokes	Median activation	IQR	Median clipping
Eastern	20	189.94	54.70	7.20%
Semi-Western	20	258.44	124.57	13.57%
Western	20	209.32	35.46	9.02%

Table 1. Preliminary EMG measurements across forehand grips

Semi-Western also showed the greatest variability and signal clipping. All 20 Semi-Western and Western strokes, along with 15 Eastern strokes, exceeded a provisional 5% clipping threshold. This saturation limits the accuracy of comparisons between grips.

3. Backhand Style Comparison

Thirty candidate strokes were analyzed per backhand style. The right forearm served as the primary hitting arm during one-handed backhands and as one of two participating arms during two-handed backhands.

Backhand style	Strokes	Median activation	IQR	Median clipping
One-handed	30	128.54	31.67	4.21%
Two-handed	30	146.55	21.51	4.02%

Table 2. Preliminary EMG measurements across backhand styles

Two-handed backhands showed a higher median recorded activation and lower variability than one-handed backhands. Clipping was less common than during forehands, although five one-handed and seven two-handed candidate strokes exceeded the provisional 5% threshold.

4. Signal Quality and Limitations

Recordings showed repeated EMG bursts consistent with the approximately eight-second ball-machine feed intervals. Median stroke-window sample loss was 0% across all five conditions, although individual recordings varied in reliability.

The main measurement limitation was signal saturation, particularly during forehands. ADC clipping prevented accurate measurement of some activation amplitudes, while several automatically detected strokes remained unverified against video.

Therefore, the results are presented descriptively. No inferential statistical tests were performed, and the observed differences cannot establish injury risk or generalizable physiological differences between tennis techniques.

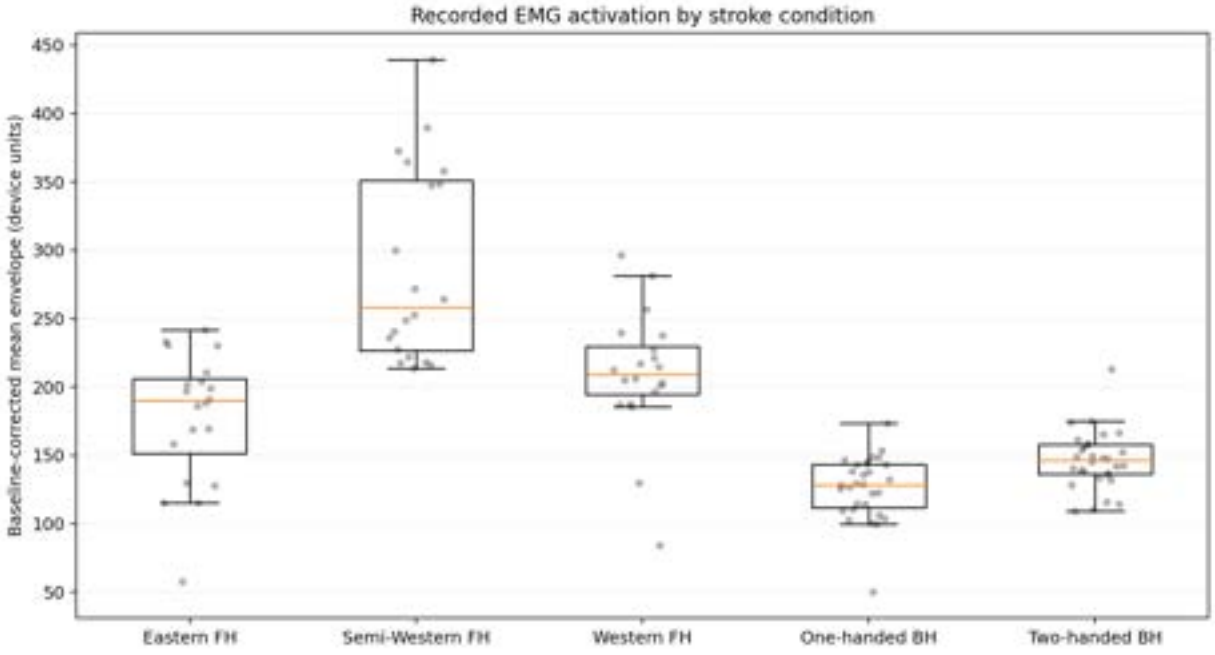


Figure 4. Distribution of mean EMG envelope amplitude across forehand and backhand grips.

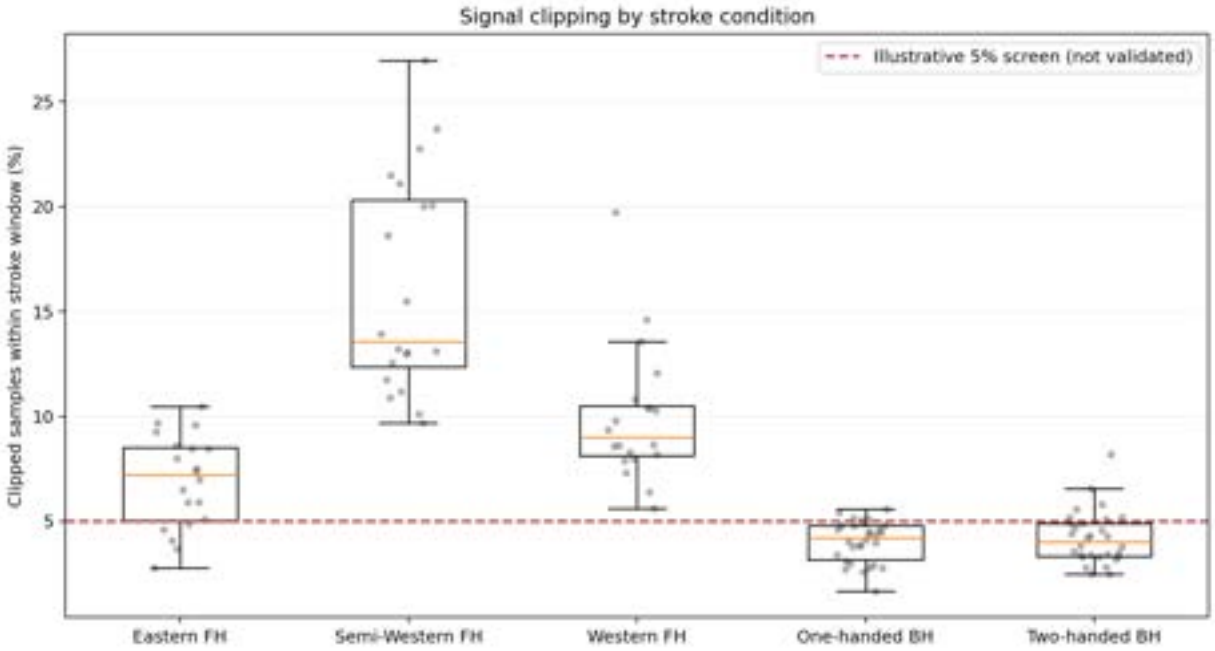


Figure 5. Percentage of clipped ADC samples within stroke windows across forehand and backhand grips.

Conclusion

This study aimed to investigate differences in recorded forearm muscle activity across three forehand grips and two backhand styles using a wireless EMG device. The Semi-Western forehand produced the highest median recorded envelope amplitude among forehands, while the two-handed backhand showed a slightly higher median amplitude than the one-handed backhand. However, frequent signal saturation, especially during forehands, prevented these differences from being interpreted as definitive differences in muscle activation.

Previous research observed differences in muscle activation associated with tennis technique. Players using Eastern forehand grips showed greater activation of certain forearm muscles than players using Semi-Western grips (Stepnik & Jones, 2023). Although this differs from this study's recorded amplitude rankings, differences in experimental design, measured muscles, and signal quality mean direct comparison is impossible. Differences in muscle activation patterns have also been observed between one-handed and two-handed backhands (Giangarra et al., 1993).

The findings also highlight the challenges of using EMG measurements to investigate tennis-related injuries. Previous research has highlighted limitations in forearm EMG studies and the need for further investigation into the relationship between muscle activation and tennis elbow (Alizadehkhaiyat & Frostick, 2015). This study also encountered similar measurement challenges, particularly with ADC clipping, while also being limited by a single participant and occasional wireless packet loss.

Future research should focus on improving sensor measurement range and including multiple participants. Recording additional muscles and using standardized procedures could also make for more reliable comparisons between tennis techniques. Although this study could not establish which strokes contribute most to tennis elbow risk, it demonstrated the potential of a wireless EMG system to capture repeated forearm activation patterns during tennis and identified technical limitations that future investigations should aim to answer.

AI Use Disclosure

ChatGPT was used to assist with data analysis and the generation of figures and diagrams. The author independently conducted the experiment, collected the data, and reviewed the AI-assisted outputs for accuracy.

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