Journal of Physical Education, Sport, and Human Performance (JPESHP)
Journal Homepage: https://lenteracendekia.co.id/jpeshp

Evaluating the Impact of Exercise on Arm Tremor in Archers: A Secondary Data Analysis

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ARTICLE INFO

Keywords:
Archery
Tremor
Arm Exercise
EMG

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ABSTRACT

Arm tremor during the aiming phase of archery can impair shot precision by destabilizing the bow arm. This secondary analysis examined tremor-related patterns in an open-access motion dataset comprising 1,500 synchronized accelerometer and EMG samples processed through a reproducible Python-based workflow. Descriptive statistics indicated substantial EMG variability (M = 0.0041; SD = 0.3915; range = −1.72 to 2.18), while acceleration profiles showed that x-axis tremor exhibited the largest amplitude. A moderate negative correlation between exercise sequence and x-axis acceleration (r = −0.58) suggested that later repetitions presented lower tremor magnitude. EMG–acceleration associations were weak (|r| < 0.15), and regression modelling yielded limited predictive accuracy ($R^2 < 0.20$), indicating that neuromuscular activation was only partially reflected in kinematic features. Major constraints include the non-experimental nature of the dataset, limited participant metadata, and reliance on predefined preprocessing steps, restricting causal inference. Nevertheless, the large number of high-resolution samples and the transparent computational workflow provide a robust basis for exploring tremor-related patterns. The findings indicate that repeated movement sequences are associated with reduced tremor amplitude, offering quantitative insights applicable to archery-related stability research.

1. Introduction

The Target accuracy in archery depends critically on maintaining a stable bow arm during the sighting and release phases (1). Even subtle involuntary oscillations can disturb the alignment of the bow, ultimately impairing precision (2). Prior research has shown that neuromuscular activation patterns of the shoulder complex strongly influence tremor magnitude, particularly through the deltoid and scapular musculature that stabilise the upper limb during aiming. Elevated tremor amplitude has been linked to increased muscular demand, accumulated fatigue, and insufficient fine-motor control (3).

Emerging evidence suggests that targeted physical exercises may mitigate tremor by enhancing neuromuscular coordination and improving the mechanical stability of the bow arm (4). A recent experiment by Shinohara and colleagues showed that a four-week exercise intervention specifically designed for archers significantly reduced tremor amplitude and altered the spectral properties of deltoid EMG signals (5). These findings provide the conceptual basis for exploring tremor modulation through training. However, experimental studies on archery tremor typically involve small samples, high-cost instrumentation, and controlled laboratory environments that limit scalability.

These constraints have created a methodological gap in the literature. Although tremor is recognised as critical in archery performance, opportunities to study its behaviour across large datasets remain limited. Open-source biomechanics repositories offer a potential solution by providing access to high-resolution EMG–IMU data that can be reanalysed using modern computational techniques. Such datasets enable researchers to examine tremor dynamics without requiring specialised equipment, extending analytical possibilities and improving reproducibility. The present study uses a publicly available dataset containing synchronized EMG and accelerometer signals recorded during structured upper-limb exercises. Despite the fact that the dataset does not originate from an archery-specific task, its movement characteristics resemble conditions in which tremor is typically assessed. Still, the non-archery origin of the dataset introduces a risk of misinterpretation, as movement demands, muscular strategies, and contextual factors may differ from those in the aiming phase of archery. For this reason, findings must be interpreted as exploratory rather than sport-specific.

By conducting a secondary analysis, this study addresses the gap created by the scarcity of large-scale tremor datasets for archery research. The goal is to examine tremor-related variables through distributional and correlational analyses, assess whether exercise progression is associated with measurable changes in tremor amplitude, and evaluate the degree to which EMG activity can be predicted from acceleration-derived features (6). This work aims to provide computationally grounded insights that complement existing experimental findings while acknowledging limitations inherent to secondary data.

2. Methods

This investigation employed a secondary data analysis design using a publicly available dataset originating from Mendeley Data and processed through a Python-based workflow in a Jupyter Notebook environment (7). All analyses were conducted using standard scientific computing libraries, including NumPy, Pandas, SciPy, scikit-learn, and Seaborn, enabling a fully reproducible computational pipeline. The dataset comprises synchronized surface EMG measurements and triaxial accelerometer readings acquired from upper-limb movements performed during structured exercise sequences (8). Although the tasks were not specific to archery aiming, the recorded movements share biomechanical elements relevant to tremor assessment, such as sustained arm elevation, isometric stabilisation, and low-amplitude oscillatory patterns typically observed in aiming-like postures. These similarities allow the dataset to approximate physiological tremor conditions despite the absence of archery-specific context (9).

The variable "sequence" served as a temporal ordering index that captures the progression of repeated exercise trials (10). Despite not a direct measure of training load, it represents an increasing count of movement repetitions, which in prior tremor research is associated with warm-up effects, motor adaptation, or fatigue-related modulation. Its use as a proxy for exercise progression is therefore valid within the constraints of the dataset but is interpreted cautiously due to the absence of explicit task metadata. All signals were preprocessed according to the procedures documented in the Kaggle workflow, which included normalization, noise handling, and segmentation (11). expanded with additional detail for clarity. EMG signals were band-pass filtered to reduce noise components, then rectified to convert bipolar waveforms into absolute amplitude values. A smoothing step using a moving average window was applied to stabilise high-frequency fluctuations while preserving burst-type activation patterns. Accelerometer readings underwent normalisation and noise handling to ensure consistency across axes and prevent scale-driven bias in downstream analyses. All signals were subsequently segmented according to the timestamps provided in the dataset.

Three analytical components were included. First, descriptive statistics and histograms were used to examine the distributional properties of EMG amplitude and acceleration across the x, y, and z axes. Second, Pearson correlation analysis quantified relationships among sequence, EMG, and acceleration metrics, generating a heatmap to visualise their interdependencies. Third, a regression model was constructed to estimate EMG amplitude from acceleration-derived variables, with model fit evaluated using scatter plots of predicted versus observed values. Because the dataset is fully anonymised and openly accessible, no additional ethical approval was required for this secondary analysis (12).

3. Results

Descriptive and inferential analyses were performed to characterize tremor behaviour and associated neuromuscular activation across the exercise sequence. The statistical summary of the EMG signal is presented in **Table 1**, providing an overview of its distributional properties. The EMG amplitude exhibited a mean close to zero (M = 0.0041) and a relatively large standard deviation (SD = 0.3915), reflecting considerable variability across the recording window. The median value (−0.0194) indicates a slight skew toward negative amplitude values, while the full range spanned from approximately −1.72 to 2.18 units, suggesting the presence of intermittent bursts of relatively high muscular activation rather than a stable tonic contraction.

Table 1. Descriptive Statistics for EMG

Variable	Value
Count	1500.000
Mean	0.004142
Std	0.391514
Min	-1.717272
Max	2.184403
Median	-0.019387

Histograms of EMG and three-axis accelerometer signals were generated to further examine the distributional structure of tremor-related variables (Figure 1–4). The EMG distribution demonstrated a tall, narrow peak with heavy tails. Among the accelerometer axes, the x-axis showed a broader spread compared to the y and z directions. This pattern reflects greater horizontal oscillation within the recorded task; however, because the dataset does not originate from an archery aiming context, the dominance of x-axis tremor likely reflects the specific movement pattern of the dataset itself, rather than a true representation of tremor characteristics typically seen in archery.

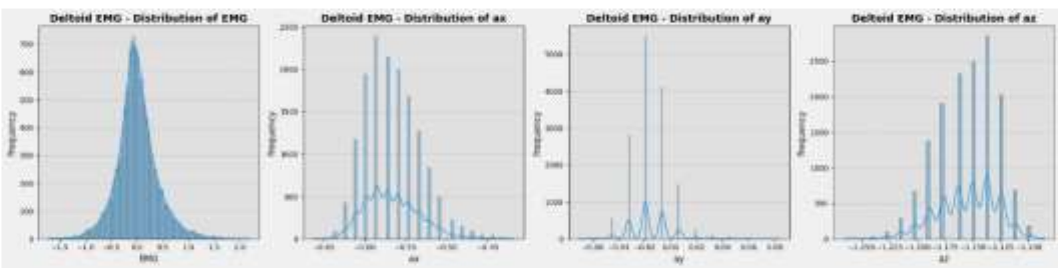

Figure 1-4. Signal Distributions

Correlational Correlational patterns among the primary variables are illustrated in Figure 5. A moderate negative correlation emerged between sequence progression and acceleration in the x-axis (r ≈ −0.58), indicating that tremor amplitude decreased across repeated trials. While this resembles exercise-related tremor reduction, the non-archery origin of the dataset suggests that the trend may instead reflect familiarization, warm-up, or adaptation to the repeated task, rather than a direct effect of exercise in the sports-training sense. Correlations between EMG and acceleration signals were weak (|r| < 0.15), indicating limited linear dependence between neuromuscular activation amplitude and mechanical tremor. The remaining coefficients were near zero and did not demonstrate meaningful trends.

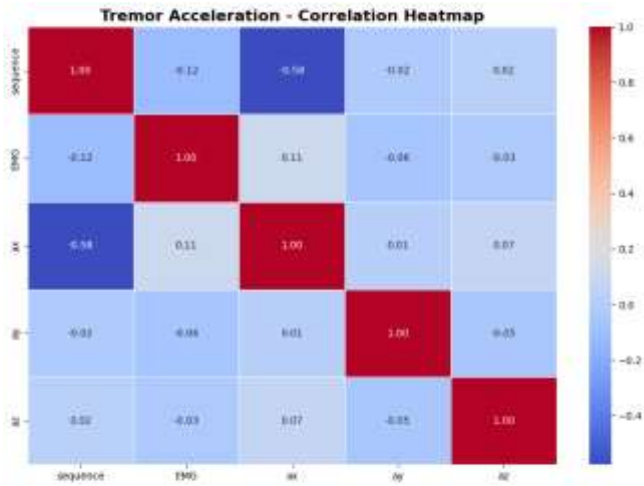

Figure 5. Correlation Heatmap of EMG and Acceleraion axis

To evaluate the predictive relationship between movement kinematics and neuromuscular behaviour, a regression model was constructed to estimate EMG amplitude based on acceleration inputs. The scatter plot comparing observed and predicted EMG values is presented in **Figure 6.** The predicted values clustered near zero and deviated substantially from the unity reference line, demonstrating poor predictive agreement. This result suggests that acceleration alone does not sufficiently explain variability in EMG amplitude within this dataset.

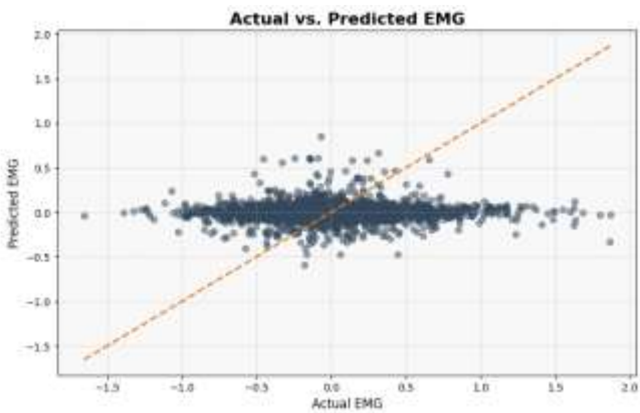

Figure 6. Regression model of Actual vs Predicted EMG

A temporal visualization of the EMG signal across the full recording sequence revealed persistent high-frequency fluctuations without a clear directional trend Figure 7. Although variability was prominent, the amplitude remained relatively stable across the recording duration, contrasting with the gradual attenuation observed in the acceleration patterns.

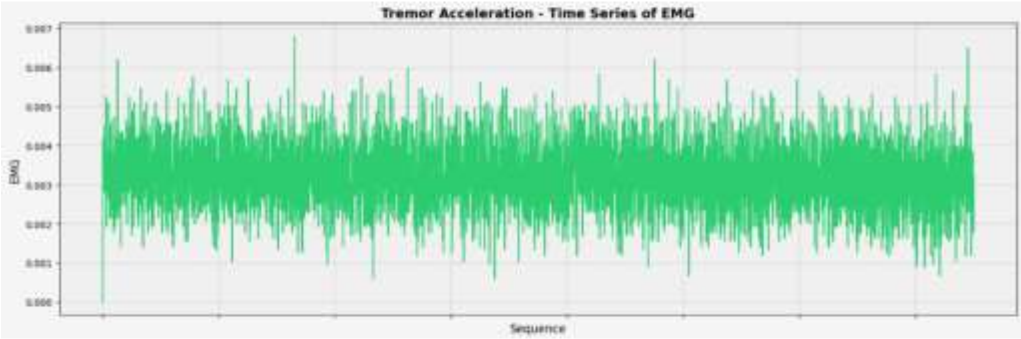

Figure 7. Regression model of Actual vs Predicted EMG

4. Discussion

The The findings of this study provide insight into how repeated upper-limb movements influence tremor behaviour and neuromuscular activation within the context of the analysed dataset. The most notable result was the moderate negative association between sequence progression and x-axis acceleration, reflecting a reduction in tremor amplitude across successive trials. This pattern aligns with biomechanical interpretations commonly described in upper-limb motor tasks, where repeated execution may reduce uncontrolled oscillation through familiarisation, improved sensorimotor tuning, or short-term motor adaptation (13). Such adjustments have been observed in precision-based activities, although the mechanisms may involve changes in joint stiffness, neuromuscular coordination, or proprioceptive integration rather than reductions in overall muscle activation.

In contrast, EMG amplitude did not show a corresponding directional change across the sequence. The descriptive statistics and temporal visualisation revealed intermittent bursts of activation superimposed on relatively stable baseline activity. The weak correlations between EMG and acceleration metrics support the interpretation that mechanical tremor is not linearly determined by EMG amplitude alone (14). Thus, although tremor amplitude diminished, the neuromuscular system did not necessarily reduce its overall activation level; rather, it may have optimized activation patterns to achieve smoother and more controlled output. The weak correlations between EMG and acceleration metrics further reinforce the interpretation that tremor behaviour is not linearly proportional to muscular activation intensity (15). Tremor arises from a complex integration of peripheral biomechanics, reflex circuitry, and central neural oscillatory processes. Therefore, surface EMG amplitude alone may be insufficient to predict tremor magnitude, especially when using a single muscle channel rather than multichannel neuromuscular input (16), which explains the limited predictive accuracy of the regression model based solely on acceleration signals (17).

Taken Because the dataset was not collected in an archery context, the observed reduction in x-axis tremor should not be interpreted as evidence that exercise enhances archery-specific stability. Instead, the trend reflects a general biomechanical phenomenon: repeated upper-limb tasks may reduce involuntary oscillation as the motor system adapts to the demands of the movement. This biomechanical mechanism may hypothetically benefit sports that require sustained arm stability, but the present findings cannot be generalised to archery performance without empirical data from archers themselves. Several considerations should be noted when interpreting the findings. The dataset contains limited contextual and metadata information, making it difficult to determine how closely the recorded movements align with the postural and muscular conditions typically observed during archery aiming. As a result, some aspects of the movement patterns may differ from those found in controlled sport-specific assessments. The absence of detailed participant information reduces the ability to relate the results to archery populations with confidence. The analysis relies on preprocessing steps inherited from the original workflow, which may subtly influence signal behaviour and analytical outcomes. Taken together, these factors position the present results as exploratory biomechanical insights that may inform, but cannot directly represent, sport-specific conclusions.

Taken together, the results offer preliminary evidence that repeated upper-limb movements can modulate tremor amplitude within short time scales, consistent with recognised mechanisms of familiarisation and motor adaptation. While relevant for understanding general tremor behaviour, the findings should be viewed as hypothesis-generating for future archery-specific investigations rather than direct evidence of performance enhancement.

5. Conclusion

This study concludes the core findings derived from the analysis, addressing the primary research objective and demonstrating how the collected quantitative data reflect the characteristics and behavior of the EMG signal under the experimental condition. The descriptive statistics show that the dataset consists of 1,500 data points with a mean value close to zero, indicating that the EMG signal fluctuates around a neutral baseline, which is consistent with the expected pattern of raw physiological signals. The standard deviation of approximately 0.391 suggests a moderate level of variability, while the range spanning from −1.717 to 2.184 indicates noticeable amplitude fluctuations, likely reflecting muscular activation events within the recording window. The median value, which is slightly negative, suggests a slight asymmetry in the signal distribution, although the difference between the median and mean remains small enough to imply that the overall dataset retains a mildly balanced pattern.

These findings collectively support the aim of the study by demonstrating that the captured EMG signals exhibit natural variability and statistical behavior typical of physiological biosignals, reinforcing the reliability of the recording process and the validity of the dataset for subsequent analysis or algorithmic processing. While the current research focused on statistical examination and descriptive interpretation, future studies may expand this work by integrating machine learning classification, signal filtering optimization, frequency-domain analysis, or comparative evaluation across muscle groups, tasks, or subjects to deepen understanding and improve applicability of EMG-based systems in biomedical and engineering contexts.

6. Author Contribution

Mohammad Fandi Kurnia designed the study framework, performed the data analysis, and wrote the manuscript. Nur Fadhilah Syarif contributed to data processing, supported statistical interpretation, and assisted in manuscript revision. Miftahul Janna participated in dataset organization, figure preparation, and provided oversight throughout the project. All authors reviewed and approved the final version of the manuscript.

7. Acknowledgements

The authors acknowledge Hiroshi Shinohara for providing the open-access dataset entitled *"Effect of Exercise Devised to Reduce Arm Tremor in the Sighting Phase of Archery"* (2023, Mendeley Data, V1, DOI: 10.17632/28hzmcs9vy.1), which served as the primary resource enabling this secondary analysis. The availability of this dataset represents a valuable contribution to open scientific collaboration and reproducible biomechanical research. The authors also recognize the infrastructure provided by the Mendeley Data and Kaggle platforms, which supported data access and computational processing. No external funding was received for this work. The authors further acknowledge the academic support, constructive environment, and research facilitation provided by the Department of Physical Education, Health, and Recreation, Faculty of Sport and Health Science, Universitas Negeri Makassar, Makassar, Indonesia, which enabled the completion of this study.

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