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A Comparative Electromyographic Analysis of Muscle Fatigue in Traditional Handwriting, Typing, and the Palmer Method: Implications for Ergonomic Writing Practices

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Abstract

Writing and typing are fundamental tasks in academic and professional settings, yet prolonged engagement often contributes to musculoskeletal disorders (MSDs) of the wrist, forearm, and neck. Handwriting techniques, learned early in life and maintained throughout adulthood, play a critical role in shaping ergonomic outcomes. The Palmer handwriting method, developed in the early 20th century to emphasize whole-arm rather than finger-centric movement, has largely fallen out of practice with the rise of typewriting and digital communication. This study investigates writing methods as one the understudied root causes of musculoskeletal disorders. The study compares muscle fatigue across three writing methods: traditional handwriting, typing, and the Palmer method using surface electromyography (sEMG). Twenty-four healthy participants performed standardized 10-minute tasks in each method, followed by fatigue assessments of the wrist, forearm, and neck. Results show that the Palmer method produced the lowest levels of muscle fatigue and the fastest muscle activation, followed by typing, while traditional handwriting generated the highest fatigue and slowest activation. These findings highlight the Palmer method as the most ergonomically efficient approach in terms of muscles fatigue and muscle activation pattern that can induce musculoskeletal disorders in the long term. The study provides evidence-based recommendations for promoting healthier writing practices and suggests that reintroducing ergonomic techniques such as the Palmer method could support high percentage of people through reducing fatigue and the risk of MSDs among students, office workers, and professionals engaged in prolonged writing tasks.

Keywords: Surface Electromyography (sEMG), Palmer Handwriting Method, Muscle Fatigue, Muscle Activation, Musculoskeletal Disorders (MSDs).

1. Introduction

Upper-Limb Musculoskeletal Disorders (ULMSDs) encompass a range of non-traumatic disorders of the shoulder, neck, arm, wrist, and hand, often linked to repetitive motion, awkward posture, force exertion, or sustained static position. These conditions include carpal tunnel syndrome, tendinitis, rotator-cuff disorders, tension neck syndrome, and epicondylitis. Musculoskeletal Disorders (MSDs) have a significant impact on a number of levels. They represent a professional expense for the employee whose career is interrupted by the incapacity for work. A study done to test the association between workers sick leave and musculoskeletal health found significant associations between work-related factors and MSK health. Better MSK health was linked to higher work ability and full-time employment, while poorer MSK health was associated with higher degrees of sick leave and conflict with the employer [1].

The Palmer handwriting method, introduced by Austin Palmer in the late 19th century, relies on smooth, rhythmic motions involving the larger muscles of the arm and shoulder, rather than the smaller muscles of the fingers and wrist. This technique naturally promotes a relaxed and comfortable posture, reducing the muscle tension often experienced with traditional handwriting methods. As a result, individuals using the Palmer method are less likely to suffer from upper-limb musculoskeletal disorders, especially those affecting the wrist, forearm, and neck areas[2]. By encouraging larger and more fluid arm movements, the Palmer technique evenly distributes the workload across different muscle groups, helping to minimize localized fatigue and repetitive strain injuries (RSI), which frequently occur during extended periods of writing [3].

Research has shown that traditional handwriting methods, characterized by sustained static positions and repetitive fine motor movements, increase muscular strain, leading to discomfort or pain, particularly in the wrist and

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forearm regions[4]. In contrast, the Palmer method encourages more ergonomic habits by supporting neutral wrist positioning and proper forearm alignment, significantly decreasing muscle and tendon stress [5]. Additionally, since this method promotes better overall posture and spinal alignment, it notably reduces cervical strain and associated neck pain[4]. Consequently, incorporating the Palmer handwriting method into educational and professional settings could play an essential role in preventing upper-limb musculoskeletal issues, enhancing both overall health and writing performance.

Compared to the Palmer handwriting method, typical handwriting methods usually involve more precise, repetitive finger and wrist motions, which can cause increased muscle tension and raise the risk of fatigue or repetitive strain injuries, particularly affecting the wrist and forearm [2]. Common handwriting practices also often result in prolonged static positions and awkward wrist angles, further intensifying discomfort in the upper limbs and neck area. Similarly, typing, although considered a less demanding alternative, has its own risks due to continuous finger movement and extended wrist positions, potentially leading to conditions such as carpal tunnel syndrome. On the other hand, the Palmer method promotes larger, flowing movements from the arm and shoulder, effectively reducing localized muscular stress, lessening repetitive strain, and encouraging better posture and spinal alignment, making it a more ergonomic and comfortable option for upper-limb musculoskeletal health[6].

Prolonged writing and typing activities are common among students and office workers, often leading to musculoskeletal discomfort and fatigue, particularly in the wrist, forearm, and neck regions. The increasing cases of musculoskeletal disorders in young individuals attracted the researchers interests in exploring the root causes. Despite the widespread use of digital devices and traditional handwriting methods, limited research has comparatively assessed their impact on muscular fatigue using objective measures such as surface electromyography (sEMG).

1.1. Research Gap and Significance

Although previous research has examined handwriting grips, typing ergonomics, and device interfaces, no study has directly compared traditional handwriting, typing, and the Palmer handwriting method under standardized conditions with objective sEMG measures. The novelty of this work lies in revisiting the Palmer method historically designed for ergonomic efficiency through modern physiological assessment, providing quantifiable evidence of its superiority. The study is significant as it shows that the Palmer method results in lower muscle fatigue and faster activation than both typing and usual handwriting. This has implications for occupational health, by reducing long-term MSD risk among workers, and for education, by supporting the early teaching of ergonomic handwriting techniques. The main research gap addressed is the absence of direct, controlled comparisons across these three writing modalities. By filling this gap, the study offers a scientific basis for ergonomic recommendations and future interventions aimed at promoting healthier writing practices.

2. Literature Review

Considerable research has explored how various handwriting methods and typing tasks impact muscle activation and fatigue in the hand, wrist, and neck using surface electromyography (sEMG). Queiroz de Almeida et al. [2020] compared muscle activation in 24 students using Dynamic Tripod and Static Tripod handwriting grips. Results indicated significantly greater activation of trapezius and biceps brachii muscles in the Static Tripod group, while no significant differences were observed for the extensor carpi radialis brevis and flexor digitorum superficialis muscles [7]. El-Gohary and Aljohani [2021] examined the effects of texting and handwriting on handgrip and key-pinch strength in healthy female students aged 19-23 years. Using randomized groups performing 10–15-minute texting or handwriting sessions, the authors concluded that these activities did not significantly affect hand strength [8].

Building on prior studies, Farris et al. [2022] investigated muscle activity and writing clarity across four handwriting grip methods among 34 individuals aged 18-22 years. They found that grip style affected arm stability, notably with the lateral grip method enhancing overall arm stabilization, although grip choice had limited impact on writing legibility [9]. Similarly, Yerebakan et al. [2022] assessed the biomechanical effects of writing interfaces (paper, whiteboard, tablet) and orientation (horizontal, 45°, vertical) on 14 adult participants. Their findings showed that using a tablet with a 45° angle resulted in the lowest muscular activation, indicating ergonomic benefits associated with specific interfaces and workstation orientations [10].

Several studies have specifically analyzed the impact of typing on musculoskeletal health. One study found prolonged typing (2 hours continuously) significantly reduced maximum voluntary muscle activation, indicating persistent muscle fatigue even after a recovery break. Similarly, Yu et al. [2019] reported musculoskeletal complaints among 170 female typists who typed continuously for two hours, with half experiencing pain primarily in the lower back, neck, arms, and fingers, associated largely with poor ergonomic workstation design. Rezgui et al. [2018] complemented these findings by developing a musculoskeletal model for handwriting tasks using OpenSim, providing a valuable tool for studying fine motor coordination and informing ergonomic device design [1, 11, 12].

Moreover, Lee et al. [2025] demonstrated that posture significantly influenced muscle activation patterns during smartphone usage, supporting the importance of posture assessment in ergonomic research. Collectively, these studies underscore how muscle activation varies substantially according to grip style, interface design, and ergonomic positioning [13].

However, none of the previous studies directly compared traditional handwriting, typing, and the Palmer handwriting method under uniform fatigue-testing conditions. This research addresses this gap by comparing these three methods through standardized 10-minute writing tasks while utilizing sEMG to measure fatigue consistently across identical muscle groups, providing clear, evidence-based recommendations to enhance

musculoskeletal health in academic and professional contexts.

3. Methodology

3.1. Research Design

This study used a quantitative experimental design to evaluate different writing methods in terms of muscle activation and muscle fatigue, as shown in Figure 1.

This research was performed on 24 right-handed volunteers, aged between 18 and 25 years old, have healthy BMI as shown in Table 1. The sample is a 1:1 ratio of males to females, all volunteers have no previous pain or musculoskeletal injury in the areas of interest (forearm, wrist, and neck), and all of them use writing and typing in their daily routines. See Figure 2 for an experimental procedure visualization.

3.2. Why Palmer Handwriting Method?

Traditional handwriting exerts localized strain on the wrist, thumb, and index finger due to the nonneutral wrist posture and resting hand position. This increases the likelihood of fatigue and long-term musculoskeletal issues. In contrast, the Palmer method shifts motion and pressure from the wrist to the forearm, engaging larger muscle groups more suited for repetitive activity. The wrist remains in a neutral position with no angular stress, and the fingers bear minimal pressure.

3.3. Instrumentation

The study utilized a combination of hardware tools and software programs to assess muscular fatigue in the wrist, forearm, and neck following different writing methods: usual handwriting, Palmer handwriting, and typing.

- Surface Electromyography ((sEMG) Sensors sEMG sensors (Biometrics Ltd.))were employed to monitor the electrical activity of skeletal muscles. These sensors are designed for precise muscle activity detection.
- Dynamometer: A hand dynamometer (Lafayette Hand Dynamometer Model 5030L1) was used to assess grip strength. This device is standard in evaluating hand function, particularly in cases involving potential cervical or peripheral nerve issues.
- Dumbbells: Two dumbbells (3 kg each) were used for neck fatigue testing.
- Software: Biometrics Ltd was used for recording signals received by wireless. SPSS (Statistical Package for the Social Sciences) was used for data analysis and hypothesis testing.
- Laptop, ergonomic chairs, standard pens, and A4 white paper.

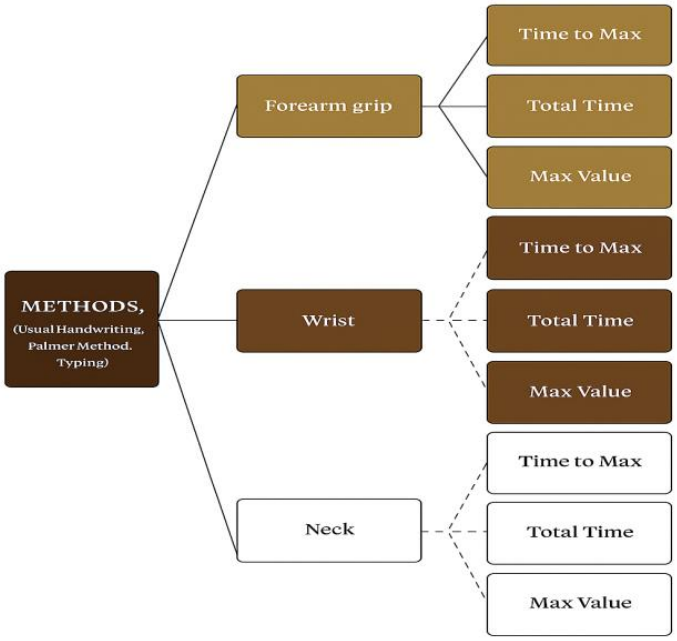

Figure 1. Research Model

Table 1. Participants Demographics

Participant ID	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24
Age (years)	24	21	22	24	20	18	22	23	22	19	25	25	21	20	21	24	18	22	25	18	19	22	20	23
BMI (kg/m2)	23.8	19.9	19.7	19.7	20.4	24.1	24.6	18.6	21.4	22.0	21.7	24.4	20.9	22.5	19.5	22.8	22.7	21.0	20.6	23.4	19.4	23.9	23.1	24.6

3.4. Experimental Procedure

A total of 24 healthy participants (12 males and 12 females), aged 18–25, were recruited. Inclusion criteria require no history of musculoskeletal disorders in the wrist, forearm, or neck. The study was conducted over multiple sessions:

- IRB Letter: The study procedure was approved by the institutional review board at the University of Jordan. Decision no. (419 / 2025).
- Consent form: all participants filled out a consent form with the experiment procedure and details.
- Pilot study: To minimize potential learning effects on experimental outcomes. Each participant in the pilot completed 10 trials of Palmer method training. Results were analyzed using one-way analysis of variance (ANOVA), which revealed a significant improvement in performance up to the 5th trial. Beyond the fifth trial, no significant change was observed. Based on these findings, all 24 participants in the main study completed five Palmer method writing tasks before formal testing procedures.
- Sensor Placement (sEMG):
Participants were seated upright with feet flat on the floor where three sensors were attached as follows: A Wireless sensor placed on the upper trapezius to assess neck fatigue, and an Extensor Carpi Ulnaris to assess forearm muscle activation. A goniometer was placed on the participant's wrist to assess wrist range of motion, as shown in Figure 3.

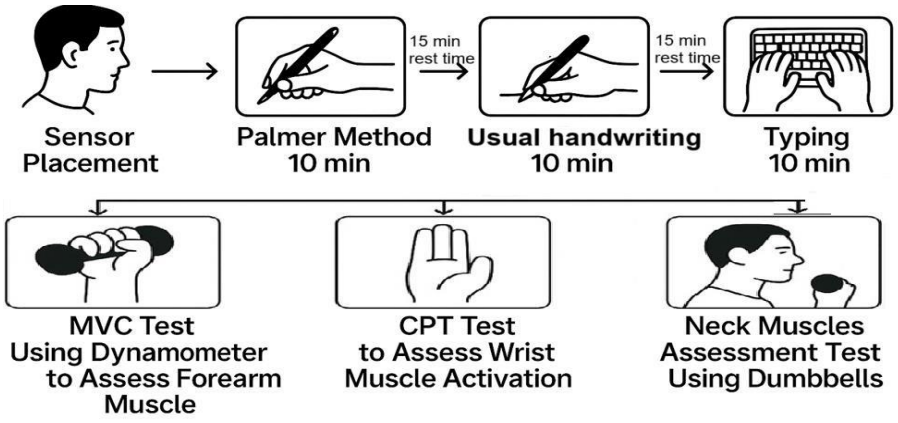

Figure 2. Experimental Procedure.

Figure 3. Sensors placement on wrist, forearm,and neck.

First writing task:

Participants were asked to perform the Palmer handwriting method for 10 minutes by copying a printed text. This method addresses many of the problems associated with traditional handwriting. In the Palmer technique, movement and tension are transferred to the larger forearm muscles, which are better equipped to handle repetitive strain without developing fatigue. The hand is not allowed to rest on the table, thereby reducing overuse of the wrist muscles. The wrist remains in a neutral position, with no bending, and the angle between the arm and wrist is maintained at zero. Minimal tension is applied to the index and thumb muscles, ensuring reduced localized strain. Furthermore, the paper is positioned at a 45° angle relative to the participant's body, while the elbow is kept at a 90° angle with the back straight, as illustrated in Figure 4. Fatigue assessment was started right after the 10 minutes and 15 minutes rest were allowed before starting the next writing task. Based on previous studies, this is long enough to allow muscles recovery [7, 8], (also, EMG signals indicate returning to baseline).

Second writing task:

Participants were asked to perform the usual handwriting for 10 minutes, by copying a text that was printed for this purpose. In usual handwriting, pressure is applied to the wrist muscles, thumb, and index finger and the hand is resting on a table, also wrist is not being on a neutral position because there is an angle between wrist and arm while writing, all of these factors affect the muscles of the hand negatively, because a high tension is applied on small region and small muscles which causes muscle fatigue, short and long term disorders such as Carpel Tunnel Syndrome. Also, in traditional handwriting there is no specific position of paper with regards to body, as shown in figure 5. Fatigue assessment was started right after the 10 minutes and 15 minutes rest were allowed before starting the next writing task.

Third writing task:

Participants were asked to perform typing on a laptop for 10 minutes, by copying a text that was printed for this purpose, as shown in Figure 6. In typing, the wrist is not in a neutral position, due to an angle between the wrist and arm, which causes tension in wrist muscles and short and long term musculoskeletal disorders for people who perform typing for long hours in daily life routines. Fatigue assessment was started right after the 10 minutes.

Figure 4. Sensors placement on wrist, forearm,and neck.

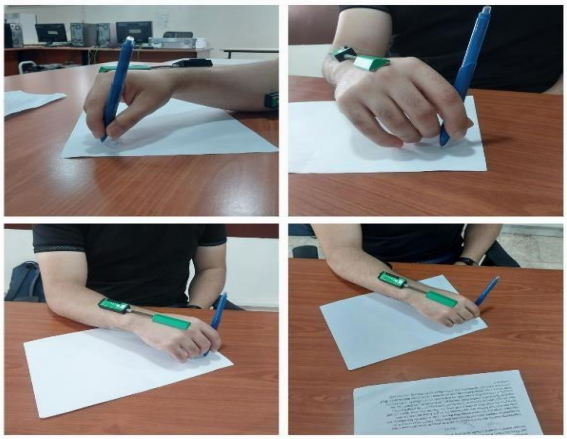

Figure 5. Multiple views showing Palmer method posture.

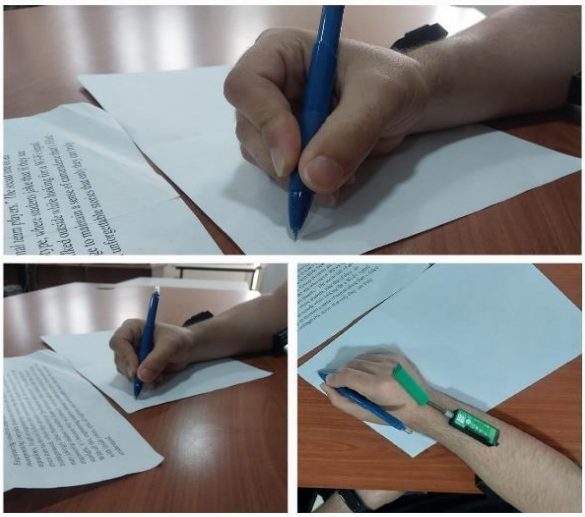

Figure 6. Multiple views showing usual handwriting posture.

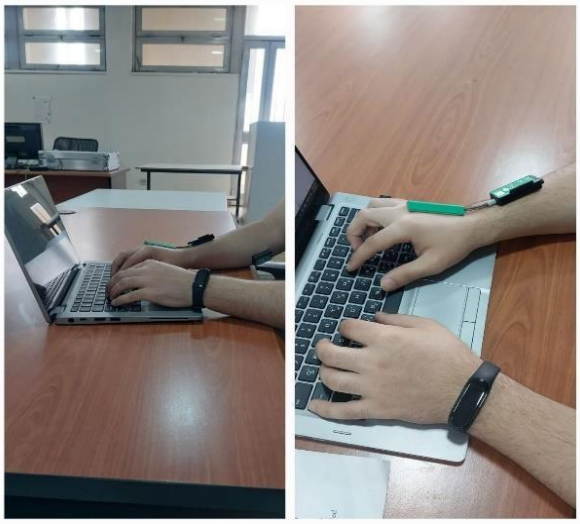

Figure 7. Typing posture

3.5. Fatigue Assessment Protocol

1. Maximum Voluntary Contraction (MVC) Test (Dynamometer):

Participants were asked to perform full grip strength trials in three positions: Neutral, Pronation, and Supination as shown in Figure 7.

Figure 8. MVC test, in neutral posture, supination and pronation.

2. Controlled Postural Test (CPT):

To assess wrist range of motion, participants executed Forced flexion and extension (Y-axis) and Ulnar and radial deviation (X-axis), as shown in Figure 8.

Figure 9. CPT in four wrist postures (a. extension, b. flexion, c. ulnar deviation, d. radial deviation).

3. Neck Fatigue Test (Dumbbells):

Participants held two 3 kg dumbbells while standing to activate the trapezius muscles and record fatigue signals, as illustrated in Figure 9.

Figure 10. Neck fatigue test using Dumbbells.

4. Data Analysis

Sensors were placed on the muscles provided, and then data gained by sEMG was collected using biometric software.

MVC test was performed in three different postures yielding three sEMG signals as shown in Figure10. For every posture, data of total test time, maximum signal effort (voltage), and time to reach maximum effort were recorded using Biometric Software. Similarly, the CPT test, which was conducted in four different postures resulted in two signals along the y-axis and two signals along the x-axis as shown in Figure 11. For every posture, data of the same variables were recorded using the same software. However, for the neck fatigue test, there was only one posture, but the movement was repeated three times to enhance the reliability and consistency of the collected sEMG data and reduce the effect of variations so the average values for the same variables ware calculated as shown in Figure 12. The real-time sEMG signals for all participants are available upon request from authors.

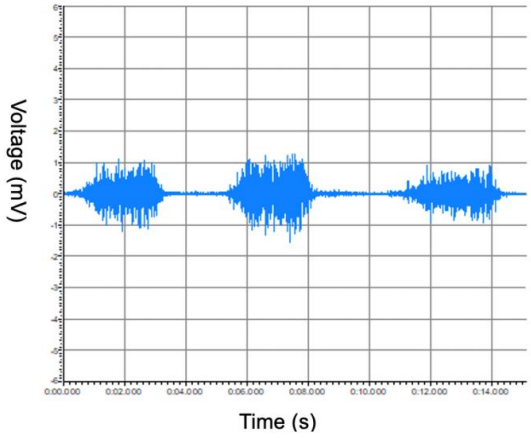

Figure 11. Signals profile for forearm MVC test in neutral position, supination, and pronation.

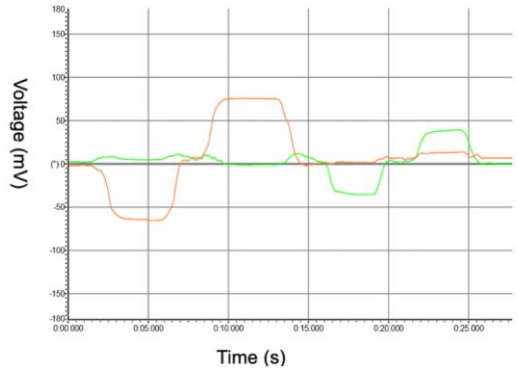

Figure 12. Signals profile for Wrist CPT in extension, flexion, ulnar deviation, and radial deviation.

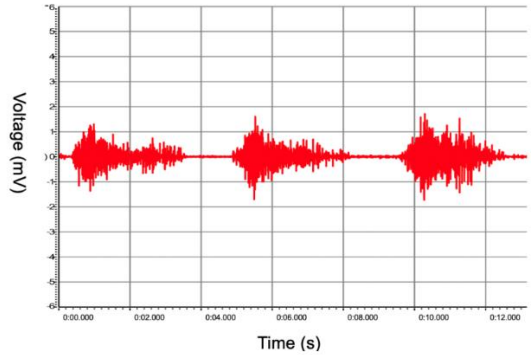

Figure 13. Signals profile for neck fatigue test.

5. Results

Descriptive statistics (mean values) were done for each of the dependent variables (Vmax, Tmax, and Tt) across the three writing methods. Vmax represents the maximum recoded voltage, Tmax represents the time required to reach Vmax, and Tt represents the total time to finish the test.

From the means values shown in Table 2, we find that the Palmer handwriting method is associated with the lowest Vmax and Tmax means indicating lower levels of muscle fatigue and faster muscle activation. In second place comes typing than usual handwriting. This makes handwriting the method with the highest fatigue levels and slower muscle activation and functioning. Data was analyzed using SPSS Software (Statistical Package for the Social Sciences).

Table 2. Mean Values by Method

Method	Mean Vmax (mV)	Mean Tmax (s)	Mean Tt (s)
Palmer handwriting	6.55	6.71	1.29
Typing	12.32	14.66	2.71
Usual handwriting	21.83	24.59	26.89

Prior to inferential testing, Q-Q plots confirmed the approximate normality of residuals for both dependent variables (Vmax and Tmax), which is acceptable for ANOVA assumptions, as shown in Figure 13 and Figure 14.

However, for the Tt variable, there was a significant deviation from the line, especially at the ends which indicates departures from normality.

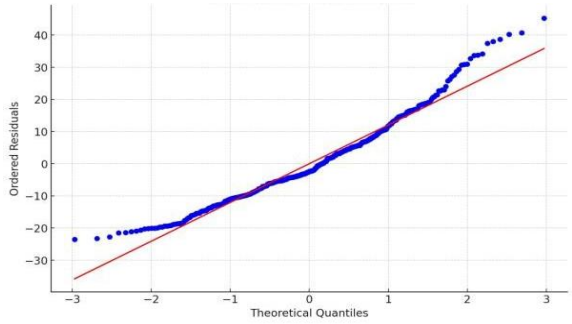

Figure 14. Q-Q Plot of Tmax Residuals.

The points in the plot closely follow the red reference line, indicating that the residuals are approximately normally distributed. There are only minor deviations at the tails, which are within acceptable bounds and do not suggest any significant departure from normality. This linear alignment supports the assumption that the residuals are normally distributed.

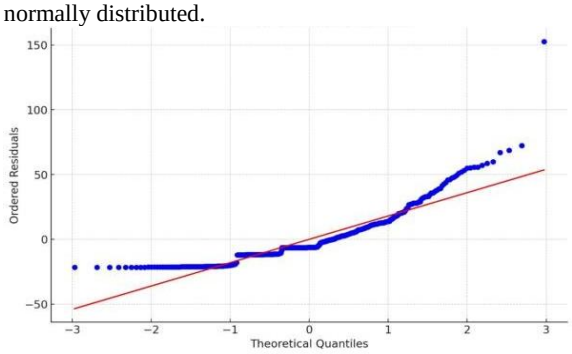

Figure 15. Q-Q Plot of Vmax Residuals.

Most of the points lie reasonably close to the reference line, particularly in the central portion of the distribution, suggesting that the residuals are approximately normally distributed. While some deviations are observed at the extremesmost notably in the upper tailthese are not pronounced enough to indicate severe non-normality. Such deviations at the tails are common in empirical data and generally do not undermine the assumption of normality if the central distributional characteristics remain intact.

A one-way ANOVA was run, and results are summarized as follows in Table 3.

Table 3. Analysis of Variance Results

Dependent variable	f-value	p-value
Vmax	23.99	0.0000
Tmax	83.81	0.0000
Tt	1.30	0.2744

The F-value in ANOVA is a test statistic used to determine whether the group means are significantly different from each other. The p-value tells you the probability of observing an F-value as extreme as (or more extreme than) the one you got, assuming the null hypothesis is true.

For Vmax, there are significant differences among methods, usual handwriting achieves the highest value. While for Tmax, there are significant differences among methods, typing takes the longest to reach it. However, for Tt, there are no significant differences.

To approve these results Tukey's test was run to define which methods are significantly different in terms of Vmax and Tmax, as shown in Table 4.

Table 4. Tukey Post Hoc Test results.

Comparison	Dependent Variable	Mean Difference	p-value
Palmer vs. Typing	Vmax	5.779	0.026
Palmer vs. Usual	Vmax	15.284	<0.001
Typing vs. Usual	Vmax	9.505	<0.001
Palmer vs. Typing	Tmax	7.951	<0.001
Palmer vs. Usual	Tmax	17.88	<0.001
Typing vs. Usual	Tmax	9.928	<0.001

Based on Tukey Post Hoc test, and in terms of maximum muscle voltage (Vmax) and time to reach the maximum voltage (Tmax), it is seen that the largest and highly significant difference between usual handwriting and Palmer method is that muscles apply more effort and need more time to reach the maximum voltage when performing usual handwriting compared to Palmer method. In the second place comes the difference of means between typing and handwriting indicating lower muscle activation and less time required to reach Vmax during typing than usual handwriting and , finally the difference between Palmer method and typing showing more muscle activation and more time needed to reach Vmax in typing than Palmer method. All differences are statistically significant, the whole differences lead to conclude that the palmer method is the most ergonomic writing method with the least and the quickest muscle activation making this method the most efficient, in the second place comes typing, and the last one is usual handwriting.

5.1. Gender Disparities

The ANOVA test was run to test the main effect of gender on the relationship between the writing method and Vmax, Tmax, and Tt. The results show no significant difference in the Vmax between males and females, regardless of the method used. The very high p-value (close to 0.78) indicates that gender alone does not influence muscle activation in a statistically or practically meaningful way. This suggests that both genders exert similar maximum muscle output under these tasks when averaged across all writing methods. To further confirm these results, the interaction effect between Method and gender was tested. The findings approved that the interaction between gender and method is not statistically significant ($p = 0.868$), meaning that the impact of the writing method on muscle performance (Vmax) does not differ by gender.

6. Discussions

This study compares the effect of usual handwriting, typing, and Palmer method in terms of muscle activation and muscle fatigue by using Surface Electromyography Sensors through analyzing three dependent variables (Vmax, Tmax, Tt) across the different writing methods, aiming to determine the ergonomically safest and most efficient writing method. This is a population-based intervention study that would benefit a large group of the society including students (KG, school, college, higher education), Journalists and writers, and Office workers.

The data were analyzed using descriptive statistics in SPSS, revealing that usual handwriting produced the highest mean values for Vmax, Tmax, and Tt, indicating greater muscle tension, fatigue, and slower muscle activation. Typing showed intermediate values, likely due to ergonomic factors such as keyboard design allowing moderate muscle use with faster movement repetition.

The Palmer method showed the lowest muscle fatigue and fastest activation, suggesting superior ergonomics. Q-Q plots indicated that Vmax and Tmax were normally distributed, while Tt was not.

ANOVA confirmed statistically significant effects of the writing method on muscle activity, and a Tukey HSD post hoc test further revealed significant differences between Palmer and usual handwriting, typing, and usual handwriting, and Palmer and typing, highlighting the Palmer method as the most efficient and ergonomic approach, followed by typing, then usual handwriting.

So based on all tests, the Palmer method is the most ergonomic and efficient method by occupying the least muscle fatigue and muscle activation, because it shifts motion and pressure from the wrist to the forearm, engaging larger muscle groups more suited for repetitive activity. The wrist remains in a neutral position with no angular stress, and the fingers bear minimal pressure with 45° angle paper position relative to the participant's body to optimize ergonomic alignment.

In the second place comes typing possibly reflecting ergonomic factors like keyboard angles that need moderate muscle activation but allow more rapid movement repetition and finally usual handwriting because it exerts localized strain on the wrist, thumb, and index finger due to the nonneutral wrist posture and resting hand position. This increases the likelihood of fatigue and long-term musculoskeletal issues.

Based on these findings, this research has a large effect on implications concerned with ergonomics, especially for individuals who spend long hours engaging in manual documentation or typing. Awareness of writing methods and muscular efficiency can reduce the risk of repetitive strain injuries, also it is concerned with education by training students in early education stages to writing using Palmer method which could reduce the short and long-term effect on muscles due to writing tasks and occupational health.

While many studies have looked at wrist and forearm strain from typing and regular handwriting, very few have actually compared different writing methods using clear, measurable indicators like maximum muscle activity (Vmax), the time it takes to reach that activity (Tmax), and how long the muscle is engaged overall (Tt). More importantly, the Palmer method, a classic handwriting technique that's often overlooked todayhasn't been properly studied using surface EMG to see how it stacks ergonomically against more common writing styles. This study shows that the Palmer method is the most ergonomic and efficient of the three methods tested. It helps reduce stress on small hand muscles by promoting better posture and less bending at the wrist. The results suggest that teaching the Palmer method early onespecially in elementary and middle schoolscould help protect students from developing muscle strain or fatigue from writing over time. People who spend a lot of time writing or typing, like office workers or journalists, could benefit from this

research by switching to writing techniques that rely more on larger muscle groups, which are better suited to handle repetitive tasks with less fatigue.

Current results reinforce prior findings that traditional handwriting imposes higher strain on small muscle groups. Queiroz de Almeida et al. [9] and Farris et al. [10] showed that grip style affects muscle activation and stability, consistent with our observation that usual handwriting led to greater fatigue. Yerebakan et al. [11] highlighted the ergonomic value of proper interface orientation, which parallels the benefits of the Palmer method's 45° paper alignment. Typing outcomes in our study also align with Lin et al. [12] who reported muscle fatigue and discomfort during prolonged keyboard use. Moreover, posture-related studies such as Lee and Son [13] underscore the importance of ergonomic positioning, supporting our finding that the Palmer method, with neutral wrist and forearm alignment, outperforms both typing and traditional handwriting.

Implications

This study extends existing work by directly comparing three writing methods under uniform conditions. The Palmer method proved most ergonomic, reducing localized fatigue by engaging larger muscle groups. These results suggest practical applications: introducing Palmer-based training in schools could help prevent early musculoskeletal strain, while professionals who rely on extensive writing or typing may reduce fatigue by adopting more ergonomic techniques.

7. Conclusions

This research compared three writing methods: Usual handwriting, Palmer handwriting, and typing by assessing muscle fatigue and muscle activation across the wrist, forearm, and neck using surface electromyography. Structured duties and standardized postural tests were performed on 24 healthful participants to assess muscle fatigue in the wrist, forearm, and neck. The results of the ANOVA statistical analysis demonstrated that the Palmer handwriting method is the most ergonomic writing method associated with the lowest muscle fatigue and quicker muscle activation. This suggests that moving the action from wrist to forearm, alongside retaining an impartial wrist posture, appreciably reduces strain. Typing confirmed reasonable fatigue levels, with quicker muscle activation in contrast to typical handwriting which imposes the highest muscle fatigue and slowest muscle activation, however nonetheless greater than the Palmer method. With an emphasis on both performance and musculoskeletal health, these findings support the acceptance and presence of more effective writing methods like Palmer handwriting, in situations that require prolonged writing.

Motivation of the Work

Handwriting remains an essential task for students, professionals, and populations with high writing demands, yet it is frequently associated with fatigue and musculoskeletal strain. The present study demonstrated that the Palmer handwriting method is the most ergonomically efficient style; however, further research is warranted to explore its long-term physiological effects through longitudinal studies. Future work should also investigate contextual factors such as writing surface texture, pen type, and posture, while intervention-based studies may clarify whether systematic training in the Palmer method reduces fatigue and improves comfort over time. Expanding the sample size and including individuals with special needs would enhance the diversity and generalizability of findings, while comparative analyses with alternative ergonomic strategies could contextualize its effectiveness within a broader framework.

This study faced certain limitations. The relatively homogeneous sample restricted the external validity of the results, and the surface electromyography (sEMG) signals were subject to noise due to imperfect sensor isolation, requiring substantial preprocessing and normalization. These challenges highlight the need for improved methodological rigor and more inclusive designs in future ergonomic handwriting research.

Regarding the sample size, we recruited 24 participants (12 males, 12 females), which aligns with similar electromyographic studies on handwriting and typing that used sample sizes ranging from 14 to 34 participants [7, 9, 10]. While relatively modest, the sample was balanced by gender and homogenous in age and BMI, which enhanced internal validity and reduced variability. Moreover, the "within-subjects design", where each participant performed all three writing methods, increased statistical power and reduced the need for larger groups. This methodological approach supports the robustness of the findings despite the moderate sample size.

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