The Relationship Between Muscle Activation and Handwriting Quality with Different Grip Styles

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Abstract

Purpose: This study identified the differences in muscle activity, handwriting legibility, and consistency when using the four primary handwriting grip styles: dynamic quadrupod (DQ), dynamic tripod (DT), lateral quadrupod (LQ) and lateral tripod (LT). It was hypothesized that different writing styles would alter muscle recruitment, writing legibility, and consistency. **Methods**: Thirty-four 18-22-year-old subjects underwent three protocols consisting of a handwriting legibility test and a consistency and handwriting metrics protocol. The legibility test was conducted on paper. The consistency and metrics protocols included surface electromyography (EMG) to measure the activity of 6 muscles associated with handwriting and were performed on a digital tablet. The tablet measured stroke duration, length, velocity, and pen pressure. Subjects used each grip style with all protocols and scores were normalized to their native grip. Grip styles were compared using a RM ANOVA, t-tests, and correlations to evaluate relationships. Significance was set at $p<.05$ and a trend towards significance at $p<.10$. **Results:** Females had a lower range in legibility scores than males by 3.483% ± 1.676% ($p=.046$), but grip style did not impact legibility. The upper trapezius (UT) was more active in the lateral grips compared to DT by 15.9% ± 5.2% and by 14.6% ± 3.7%,($p=.028$, $p=.004$, respectively). DT had more extensor carpi ulnaris activity than LT by 9.7% ± 3.3%, ($p=.011$). The stroke duration was greater in the LQ grip style than DT grip style ($p=.019$). **Conclusion:** Lateral grip styles involve more whole-arm, stabilizing movements while dynamic grip styles require fine dexterous movements. In rehabilitation, a patient with little gross muscle ability, such as the UT, should use a dynamic grip style to regain handwriting ability or use lateral grip styles to build muscle tone. Patients with poor dexterity should avoid DT or use it to improve precision. LQ was an uncomfortable grip style and resulted in long stroke durations, suggesting a greater need for focus during this grip style, so other grip styles may be preferred. Females are likely to be able to use any grip style with little effect on legibility, but males may see a greater drop in legibility scores. Characterizing each grip style can provide useful information for patient rehabilitation.

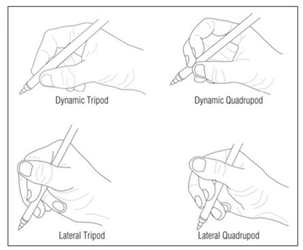
Introduction

Handwriting is a fundamental skill which allows individuals to maintain autonomy and professionalism throughout life[1].

- Stroke and injury to the hand, forearm and/or shoulder can impair this ability[2]

Occupational therapy that is specialized to the individual's impairment are essential to restore the skill of handwriting and therefore the individual's autonomy[3].

There are four established grip styles for handwriting:
dynamic tripod (DT), dynamic quadrupod (DQ), lateral tripod (LT) and lateral quadrupod (LQ)[4]



The effect native grip styles have on handwriting has been studied but no one has specifically looked at non-native grips.

The purpose of this research was to identify differences between grip styles in handwriting legibility, consistency, and muscle activity in order to provide useful information for patient rehabilitation.

Results

- Each score was normalized to each subject's native grip style and presented as a percentage of the native grip style's score
- Greater UT activity was significantly correlated with lower consistency scores for both the DT ($r= -.709$, $p=.000$) and DQ grips styles ($r=-.509$, $p=.002$).
- Greater UT activity significantly correlated with higher consistency scores for the LT grip style ($r=.513$, $p=.002$)
- Greater FPB activity correlated with a lower consistency score ($r = -.300$, $p = .085$) in the LT grip style.

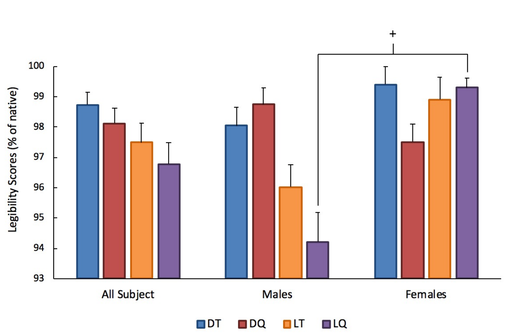


Figure 1. Normalized legibility scores (mean ± SE) presented as a percentage of native scores for all four grip styles over all subjects and separated by sex. When comparing scores of all subjects, DT produced the greatest legibility while the LQ grip resulted in the lowest legibility. When divided by sex, the DQ grip resulted in the greatest legibility scores in males but the lowest legibility scores in females. Additionally, LQ legibility scores for males trended towards being lower than the LQ scores for females (+ $p<.1$).

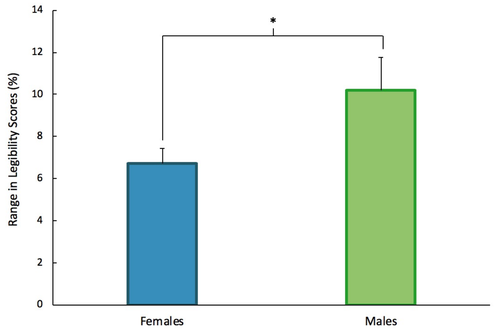


Figure 2. Percent range in letter legibility scores (mean ± SE) between males and females across all grip styles. Females had an average range across all grip styles of 6.73% ± 0.68% which was significantly less than the males average range of 10.22% ± 1.53% (*$p<.05$).

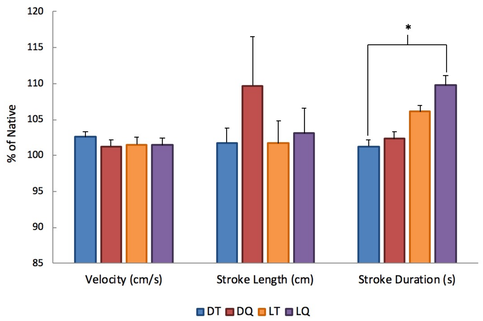


Figure 3. Normalized average scores for velocity, stroke length and stroke duration handwriting metrics (mean ± SE) presented as a percentage of native scores. Velocity was similar among all four grip styles, but the DQ grip style resulted in the highest stroke length among all four grips. The LQ grip style resulted in the greatest stroke duration, which was significantly different from that of the DT grip style (*$p<.05$).

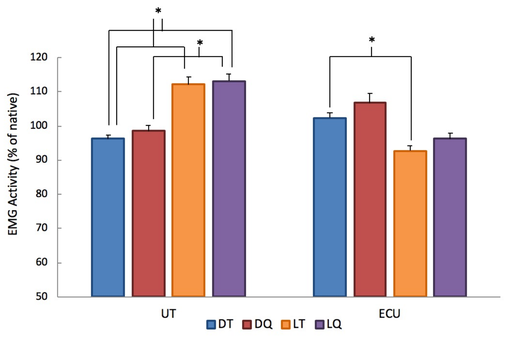


Figure 4. Normalized average EMG activity (mean ± SE) presented as a percentage of the native's value for each grip style of the upper trapezius (UT) and extensor carpi ulnaris (ECU). Overall in the UT, muscle activity was less in the dynamic grips. UT activity for DT was significantly less than LT and LQ (*$p<.05$) while DQ was significantly less than LQ. In the ECU, muscle activity was significantly different between DT and LT grip styles (*$p<.05$).

Discussion

- The UT has been shown to be a stabilizing muscle for handwriting[8]. Per our results, lateral grips require greater whole-arm stabilization than dynamics.
- Dynamic grip styles, especially DT, required more extrinsic hand muscle use, such as the ECU. Suggested by Elliot and Connolly, this extrinsic muscle use is needed to produce fine dexterous movements[9].
- In dynamic grips, more UT recruitment was related to a decrease in consistency.
  - This could be because of the localized force on a writing utensil creating a more naturally stable grip. Thus, UT recruitment is less needed[10,11].
  - Per our results, UT is recruited less in dynamic than lateral grips.
- In lateral grips, more UT recruitment was related to an increase in consistency.:
  - Although no grip style is more advantageous to handwriting legibility and consistency, it is important to note that lateral grips must recruit more of the UT in order to produce similar handwriting consistency to that of dynamic grips.
- LQ was anecdotally an uncomfortable grip style and resulted in longer stroke durations. This could be due to greater focus and attention required on behalf of the writer while utilizing a more difficult grip style.
- Females produced less variability in legibility scores and performed better than males in the LQ grip style.
  - With non-native grip styles, grip style is irrelevant for females while males will perform better with DT or DQ, and somewhat better with LT than LQ.

For handwriting rehabilitation, it may be helpful for therapists to reference Table 1 when assigning a grip style to new patients in order to ensure optimal results for both legibility and muscle use.

Table 1. Characterization of the four most common grip styles.

DT	DQ	LT	LQ
✓ legibility: good for both sexes	✓ legibility: good for both sexes	✓ female legibility	✓ female legibility
fine dextrous movement: high ECU use		~ male legibility: decent, but not preferred.	⊘ male legibility: improves with greater FPB activation
		whole arm movements: high UT use	⊘ awkward and difficult: longer stroke duration, most uncomfortable
			whole arm movements: high UT use

✓ = good; ⊘ = poor; ~ = fair

Methods

34 college undergraduate students (17 male, 17 female)
Native Grips: 14 DT, 10 DQ , 5 LT, 5 LQ

Legibility Protocol:

- For each grip style, the alphabet (uppercase and lowercase) and the sentence "John saw the red truck coming" were written on paper
- Handwriting Assessment Battery for Adults[5,6] was used to score legibility of each grip

Consistency Protocol:

- A triangle was drawn on a digital tablet 3x per grip style. Stroke length, stroke duration and velocity were collected and analyzed using a signal to noise ratio[7] to produce a consistency score per grip

Handwriting Metrics Protocol:

- The word "coming" was written on a digital tablet 3x per grip style. Pen pressure, velocity and stroke duration was collected and averaged across all trials.

EMG:

- Wireless surface electrodes attached to 6 muscles: *Upper trapezius (UT), flexor pollicus brevis (FPB), extensor carpi ulnaris (ECU), extensor carpi radialis (ECR), flexor carpi ulnaris (FCU), and flexor carpi radialis (FCR)*
- EMG activity was collected for all consistency and handwriting metric trials. The root mean square was analyzed to produce an EMG consistency score and average EMG activity for each muscle as well as overall muscle activity for each grip

Data Analysis:

- Repeated measures ANOVA compared grip styles for all variables, t-tests compared sexes and correlations evaluated relationships between variables
- Significance was set at $p<.05$ and a trend towards significance set at $p<.10$

Consistency protocol with EMG electrodes.

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