

Ergonomic Factors Affecting Handwriting Performance in Adolescents: The Role of Pen Diameter, Grip Pattern, and Gender

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Abstract

Handwriting is a complex fine-motor skill influenced by ergonomic and biomechanical factors, including pen characteristics and grip patterns. Variations in pen diameter and grip type may affect writing efficiency, yet evidence on their influence on handwriting speed among adolescents is limited. This study aimed to investigate the effects of pen diameter and pen grip pattern on handwriting speed in high school students and to explore gender-related differences.

A cross-sectional analytical study was conducted among 100 high-school students. Participants were assessed for their habitual pen grip pattern and performed a standardized handwriting task using pens of different diameters. Handwriting speed was measured in words per minute (WPM), and legibility was assessed with rubric scale. Demographic characteristics, grip type, and gender were recorded. Statistical analysis was performed to compare handwriting speed across pen diameters, grip patterns, and gender groups, with significance set at $p < 0.05$.

The findings suggest that ergonomic characteristics of writing instruments and grip mechanics influence handwriting efficiency in adolescents. Appropriate pen diameter may enhance comfort, control, and motor performance during writing tasks.

Pen diameter and grip pattern significantly influence handwriting speed among high-school students. Consideration of ergonomic writing factors may help optimize handwriting performance in educational settings.

Keywords:

Handwriting Speed, Pen Diameter, Pen Grip, Ergonomics, High-School Students

Introduction

Handwriting continues to be a fundamental academic skill despite the rapid expansion of digital technology in education. Students regularly rely on handwriting for note-taking, examinations, assignments, classroom activities, and communication. Efficient handwriting is therefore essential for academic success and participation. Handwriting is a highly complex activity involving the integration of cognitive processes, visual perception, sensory feedback, motor planning, postural control, and fine motor coordination. Successful handwriting requires coordinated movements of the fingers, hand, wrist, forearm, and upper limb while maintaining attention and accuracy.

Two major indicators of handwriting performance are writing speed and legibility. Writing speed refers to the amount of written work produced within a specified period, whereas legibility refers to the clarity and readability of written text. Both parameters are important in educational settings. Students with slow handwriting may struggle to complete examinations and assignments within time limits, while poor legibility can negatively affect communication and academic evaluation.

Several intrinsic and extrinsic factors influence handwriting performance. Intrinsic factors include age, gender, cognitive ability, hand dominance, motor coordination, muscle strength, and sensory

integration. Extrinsic factors include posture, writing surface, classroom environment, paper orientation, pen characteristics, and grip style. Among these factors, pen diameter and grip pattern are particularly important because they directly affect hand biomechanics and writing efficiency.

Pen diameter influences the amount of force required to grasp and control a writing instrument. Thin pens may require greater pinch force and increased muscular activity, potentially contributing to fatigue and reduced writing efficiency. Larger diameter pens may distribute pressure more evenly across the fingers and reduce muscular effort. However, excessively large pens may compromise precision and fine motor control. Determining the most appropriate pen diameter is therefore important for optimizing handwriting performance.

Grip pattern is another major ergonomic factor affecting handwriting. Common grip patterns include dynamic tripod, lateral tripod, dynamic quadrupod, and lateral quadrupod grips. The dynamic tripod grip is traditionally considered the most efficient because it facilitates controlled finger movement while maintaining stability. Nevertheless, many individuals naturally adopt alternative grips without obvious handwriting difficulties. The influence of grip pattern on handwriting speed and legibility remains an area of active investigation.

Gender differences have also been reported in handwriting research. Several studies suggest that females often demonstrate better handwriting legibility and fine motor performance than males. Possible explanations include differences in neuromuscular development, motor planning, attention to detail, and practice habits. However, findings are not always consistent across populations and age groups.

Adolescence is a particularly important period for studying handwriting performance because students face increasing academic demands and rely heavily on written communication. Although handwriting skills are acquired during childhood, refinement and endurance continue to develop during adolescence. Understanding the ergonomic determinants of handwriting performance during this stage may contribute to improved academic outcomes and reduced writing-related difficulties.

The present study investigates the effects of pen diameter, grip pattern, and gender on handwriting speed and legibility among adolescents. By examining these factors together, the study seeks to provide evidence-based recommendations for educators, physiotherapists, occupational therapists, and researchers interested in optimizing handwriting performance.

Need for the Study:

Handwriting difficulties remain common among school-going adolescents. Many students report discomfort, reduced writing speed, hand fatigue, and difficulty maintaining legibility during prolonged writing tasks. These problems may affect academic performance, examination completion, confidence, and classroom participation.

Most handwriting research has focused on developmental disorders, motor impairments, or educational interventions. Comparatively fewer studies have examined ergonomic factors that can be modified easily and economically. Pen diameter represents one such factor. Students typically choose pens based on preference, availability, or cost rather than ergonomic evidence. If certain pen diameters improve writing performance, simple changes in writing instruments could offer meaningful benefits.

Grip pattern is another area of clinical and educational interest. Teachers and therapists often attempt to correct non-traditional grips based on the assumption that they reduce writing efficiency. However,

the evidence supporting grip correction remains limited. Understanding whether specific grip patterns truly influence handwriting speed and legibility may help clinicians make more informed decisions.

Gender-related differences also warrant investigation. If males and females demonstrate different handwriting characteristics, intervention strategies may need to be tailored accordingly. Exploring these differences may improve understanding of developmental and biomechanical influences on handwriting performance.

From a physiotherapy perspective, handwriting is a functional task requiring strength, endurance, coordination, motor control, and efficient biomechanics. Identifying ergonomic variables that influence handwriting can support the development of assessment protocols and intervention programs aimed at improving functional performance.

Another important reason for conducting this study is the limited literature examining pen diameter, grip pattern, and gender simultaneously. Most studies evaluate these variables independently. A comprehensive investigation may provide a broader understanding of the factors affecting handwriting performance.

The findings of this study may assist educators in recommending suitable writing instruments, therapists in designing intervention programs, and researchers in identifying future areas of investigation. The study therefore addresses a relevant gap in the literature and contributes valuable information regarding handwriting ergonomics among adolescents.

Methodology

A cross-sectional observational study design was employed. The study was conducted in selected high schools after obtaining institutional permission and ethical approval.

A total of 100 adolescent students aged 13 to 18 years participated in the study. Participants were recruited through convenience sampling. Students who were able to read and write English and who had no known neurological, musculoskeletal, or severe visual impairments affecting handwriting were included. Students with recent upper-limb injuries, diagnosed neurological conditions, or significant learning disabilities affecting handwriting performance were excluded.

Prior to participation, informed consent was obtained from participants and parents or guardians where required. Demographic information including age and gender was recorded. Three pens with different diameters were used for the study: small, medium, and large diameter pens. The diameters were selected based on commonly available writing instruments and ergonomic considerations. A standardized English paragraph was used as the handwriting task for all participants.

Participants were seated comfortably in a standardized environment. Their natural grip pattern was observed and classified into categories such as dynamic tripod, lateral tripod, dynamic quadrupod, and lateral quadrupod. Each participant completed the handwriting task using all three pen diameters. Adequate rest periods were provided between trials to reduce fatigue and carry-over effects. Instructions were standardized for all participants. Students were asked to write as neatly and as quickly as possible without sacrificing readability.

Handwriting speed was measured as the number of words written per minute. Legibility was assessed using a structured scoring system evaluating letter formation, spacing, alignment, consistency of size, and overall readability.

Data were entered into statistical software for analysis. Descriptive statistics including mean and standard deviation were calculated. One-way Analysis of Variance (ANOVA) was used to compare handwriting outcomes across pen diameters. Tukey post hoc analysis was performed to identify

pairwise differences when significant effects were observed. Independent t-tests were used to evaluate gender differences. Statistical significance was established at $p < 0.05$.

The methodology was designed to ensure consistency, reliability, and validity while minimizing bias and confounding factors.

RESULTS:

Table 1. Demographic Characteristics of Participants (N = 100)

Variable	Category	n (%)
Gender	Male	50 (50.0)
	Female	50 (50.0)
Age (years)	Mean $\pm$ SD	16.1 $\pm$ 1.2
Pen Diameter	Standard (7 mm)	34 (34.0)
	Medium (10 mm)	33 (33.0)
	Large (13 mm)	33 (33.0)
Grip Pattern	Dynamic Tripod	52 (52.0)
	Lateral Tripod	22 (22.0)
	Quadrupod	18 (18.0)
	Other	8 (8.0)

Table 2. Handwriting Speed According to Pen Diameter

Pen Diameter	n	Speed (WPM) Mean $\pm$ SD
Standard (7 mm)	34	23.4 $\pm$ 3.5
Medium (10 mm)	33	26.8 $\pm$ 3.2
Large (13 mm)	33	25.1 $\pm$ 3.6
ANOVA		$F = 8.72, p = 0.001$

Interpretation: Students using the medium-diameter pen demonstrated significantly greater handwriting speed.

Table 3. Handwriting Legibility According to Pen Diameter

Pen Diameter	n	Legibility (%) Mean $\pm$ SD
Standard (7 mm)	34	84.2 $\pm$ 5.8
Medium (10 mm)	33	89.5 $\pm$ 4.9
Large (13 mm)	33	86.8 $\pm$ 5.5
ANOVA		$F = 7.15, p = 0.002$

Table 4. Handwriting Performance According to Grip Pattern

Grip Pattern	n	Speed (WPM) Mean $\pm$ SD	Legibility (%) Mean $\pm$ SD
Dynamic Tripod	52	27.0 $\pm$ 3.0	90.2 $\pm$ 4.5
Lateral Tripod	22	24.8 $\pm$ 3.1	86.4 $\pm$ 5.2
Quadrupod	18	24.2 $\pm$ 3.4	85.7 $\pm$ 5.8
Other	8	22.5 $\pm$ 3.5	81.9 $\pm$ 6.1
ANOVA		$F = 11.43, p < 0.001$	$F = 9.27, p < 0.001$

Table 5. Gender-wise Comparison

Variable	Male (n=50)	Female (n=50)	p-value
Speed (WPM)	24.6 ± 3.8	26.1 ± 3.5	0.041
Legibility (%)	85.9 ± 5.9	88.4 ± 5.2	0.028

Table 6. Summary of Key Findings

Outcome	Best Performing Group
Highest Speed	Medium Diameter Pen
Highest Legibility	Medium Diameter Pen
Best Grip Pattern	Dynamic Tripod Grip
Gender with Better Performance	Female Students

Handwriting speed varied across different pen diameters and grip patterns. Students using functional grip patterns demonstrated higher writing speeds compared to those with non-standard grips. Medium-diameter pens were associated with better handwriting performance than thinner or thicker pens. Female students demonstrated slightly higher handwriting speeds than male students; however, the magnitude of difference varied across grip categories. Significant associations were observed between pen diameter, grip pattern, and handwriting speed ($p < 0.05$).

Discussion

The findings of the present study indicate that ergonomic factors play a significant role in handwriting performance among adolescents. The results demonstrated that pen diameter influenced both handwriting speed and legibility, with medium diameter pens generally producing the most favorable outcomes.

One possible explanation for this finding is that medium diameter pens provide an optimal balance between stability and control. Small diameter pens require greater pinch force and increased activation of intrinsic hand muscles. Sustained muscular effort may contribute to discomfort, fatigue, and reduced writing efficiency. Previous biomechanical studies have reported that increased pinch force is associated with greater muscle activity and pressure on finger joints during writing tasks.

In contrast, medium diameter pens distribute pressure more evenly across the fingers while maintaining sufficient precision for fine motor control. This ergonomic advantage may facilitate smoother movement patterns and improve overall writing performance. Participants appeared to write more comfortably and efficiently when using medium diameter pens.

Large diameter pens may reduce pinch force requirements even further; however, excessively large grips can alter finger positioning and compromise precision. Fine motor control is essential for accurate letter formation and consistent handwriting. When grip size becomes too large, movement efficiency may decrease despite reductions in muscular effort. This may explain why large diameter pens did not consistently outperform medium diameter pens.

Grip pattern also influenced handwriting outcomes. Participants using a dynamic tripod grip generally demonstrated better speed and legibility compared with other grip types. The dynamic tripod grip allows efficient force distribution and controlled finger movement while maintaining stability through the ring and little fingers. This configuration has long been regarded as the most biomechanically advantageous writing grip.

However, it is important to note that alternative grips were not necessarily dysfunctional. Many participants using quadrupod or lateral grips achieved acceptable handwriting performance. These findings support emerging evidence suggesting that non-traditional grips may still be functional and

effective. Consequently, clinicians should avoid unnecessary grip correction when handwriting performance is adequate and the student experiences no discomfort.

Gender differences observed in the study were consistent with previous literature. Female participants generally demonstrated slightly higher handwriting speed and better legibility than male participants. Several explanations may account for these findings. Females often exhibit earlier maturation of fine motor skills and may place greater emphasis on handwriting quality. Differences in attention to detail, practice habits, and neuromuscular development may also contribute.

The interaction between ergonomic and demographic factors is particularly important. Hand size, grip strength, and motor control characteristics may influence how individuals respond to different pen diameters. Future research should explore these interactions further using more sophisticated biomechanical assessments.

The findings have meaningful clinical implications. Physiotherapists and occupational therapists frequently encounter students experiencing handwriting difficulties, reduced endurance, or writing-related discomfort. Recommending ergonomically appropriate writing instruments may represent a simple, low-cost intervention capable of improving functional performance.

Educational institutions may also benefit from incorporating ergonomic considerations into classroom practice. Awareness regarding pen selection, grip patterns, and writing comfort may contribute to improved academic participation and reduced fatigue during prolonged writing tasks.

Despite its strengths, the study has limitations. The cross-sectional design does not permit causal conclusions. Convenience sampling may limit generalizability. Hand fatigue was not measured using a validated scale, and muscle activity was not objectively assessed. Future investigations should incorporate fatigue measures, electromyographic analysis, motion analysis, and larger multicenter samples.

Longitudinal studies examining adaptation to different pen diameters over time may also provide valuable insight. Future research should additionally investigate the influence of hand dominance, academic level, writing duration, and digital device use on handwriting performance.

Overall, the findings support the importance of ergonomic optimization in handwriting and highlight the potential value of evidence-based pen selection and handwriting assessment strategies.

Conclusion

The present study examined the effects of pen diameter, grip pattern, and gender on handwriting speed and legibility among adolescents. The findings demonstrated that ergonomic factors significantly influence handwriting performance.

Medium diameter pens produced the most favorable outcomes for both handwriting speed and legibility, suggesting that an optimal grip size may enhance writing efficiency by balancing stability and precision. Small-diameter pens may increase muscular effort, whereas excessively large pens may compromise fine motor control.

The dynamic tripod grip was associated with superior handwriting performance, although alternative grip patterns remained functionally effective for many participants. Female students generally demonstrated slightly better handwriting speed and legibility than male students, consistent with previous findings related to fine motor development.

The results emphasize the importance of considering ergonomic variables when assessing handwriting performance. Appropriate pen selection and awareness of grip patterns may improve writing efficiency, enhance legibility, and potentially reduce writing-related fatigue in academic settings.

The study contributes to the growing body of evidence regarding handwriting ergonomics and highlights opportunities for physiotherapy, occupational therapy, and educational interventions.

Future research incorporating fatigue assessment, biomechanical analysis, and larger sample sizes is recommended to strengthen the evidence base and further explore the mechanisms underlying handwriting performance in adolescents.

Clinical Implications

The findings of this study have direct relevance for physiotherapists, occupational therapists, teachers, and school administrators. Medium diameter pens may be recommended for students who experience slow writing speed, poor legibility, or hand discomfort. Handwriting assessments should include evaluation of ergonomic factors rather than focusing solely on handwriting output. Therapists should consider grip pattern, pen characteristics, endurance, and comfort during assessment and intervention. Schools may benefit from providing ergonomic writing tools and educating students about appropriate writing habits. Such strategies may enhance academic participation, reduce fatigue, and improve overall handwriting performance.

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