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"Tracing Differences: The Role Of Age, Gender, And Bilingual Scripts In Handwriting Proficiency"

Rajkumar Gajendran[1], Sujatha Sridharan[2]
[1,2]Professor of Paediatrics, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Tamil Nadu, India.
Corresponding Author:
Rajkumar Gajendran, Professor of Paediatrics, Chettinad Hospital and Research Institute (Chettinad Academy of Research and Education)

INTRODUCTION

Handwriting is a fundamental skill in early education, serving as a primary mode of communication and a critical factor for academic achievement[1,2]. Beyond its functional role, handwriting proficiency is strongly associated with literacy development, cognitive processing, and psychosocial outcomes such as self-esteem and motivation[3,4]. Despite technological advancements, handwriting remains integral in classrooms, examinations, and early learning assessments[5]. Handwriting is a complex process involving the coordination of fine motor skills, visual-motor integration, kinesthetic feedback, and cognitive planning[6]. Difficulties in handwriting can lead to poor academic performance and emotional distress, underscoring the importance of early identification and intervention[1]. The development of handwriting skills is influenced by multiple factors, including gender, age, language, and instructional quality[7, 8]**.** Previous studies have consistently reported gender differences in handwriting proficiency, with girls outperforming boys in legibility and speed[5, 7]. This disparity is often attributed to earlier maturation of fine motor control and greater attentional focus in girls[9]. Age is another determinant, as handwriting skills are expected to improve with grade progression due to increased practice and cognitive maturity[10]. However, the extent of improvement varies, and some children continue to struggle, impacting academic outcomes**[6]**. In multilingual contexts such as India, children often learn to write in two scripts, which differ in visual complexity, stroke sequences, and spatial demands[11] (Nag & Snowling, 2012). Tamil and English scripts pose unique motor and perceptual challenges that may influence handwriting performance differently. Despite these challenges, research on handwriting development in bilingual settings remains limited. This study aims to examine the effects of age and gender on handwriting legibility among children aged 6–12 years in Tamil and English using the Handwriting Proficiency Screening Questionnaire (HPSQ). Understanding these influences will inform targeted interventions and language-sensitive educational strategies to enhance handwriting proficiency.

METHODS

Study Design and Setting

This was a cross-sectional observational study conducted in a primary school setting in Tamil Nadu, India. The study was designed to assess handwriting proficiency among bilingual school-aged children, focusing on the influence of age and gender on handwriting legibility and related parameters. The study was conducted after obtaining Institutional Ethics Committee approval and informed consent from parents.

Participants

A total of 1,013 children aged 6–12 years were enrolled in the study, comprising 517 boys (51%) and 496 girls (49%). Inclusion criteria included regular school attendance and the ability to write in both Tamil and English. Children with diagnosed neurological or developmental disorders or any other conditions likely to affect handwriting performance were excluded from the study.

Assessment Tool

The Handwriting Proficiency Screening Questionnaire (HPSQ) is a teacher-reported tool that identifies handwriting difficulties across three domains: legibility (Items 1, 2, 10), performance

time (Items 3, 4, 9), and physical/emotional well-being (Items 5–8). Each of the 10 items is rated on a 5-point Likert scale (0 = never, 4 = always), with higher scores indicating poorer performance. A total score ≥14 typically signifies handwriting difficulty[12]

For this study, the HPSQ was administered in both Tamil (after translation and back translation and pilot testing) and English scripts to account for language-specific influences on handwriting performance.

Data Collection Procedure

The class teachers of each participating child completed the HPSQ questionnaire after observing the children's handwriting performance during regular classroom activities. In addition to handwriting assessment, demographic details (age, gender) were recorded for all participants. The HPSQ scores were obtained separately for Tamil and English and included total and subscores.

Data Analysis

All collected data were entered and analyzed using SPSS software (version XX). Descriptive statistics (mean, standard deviation) were calculated for continuous variables. Gender-based differences were assessed using independent t-tests, while the effect of age on handwriting scores was examined using linear regression analysis. The results were visualized using box plots for gender differences and scatter plots to depict age-related trends in handwriting performance. A p-value of <0.05 was considered statistically significant.

RESULTS:

A total of 1,013 children participated in the study, comprising 517 boys (51%) and 496 girls (49%) (Table 1). The majority of participants were in the 4th grade (25.0%), followed by 7th grade (22.1%), 5th grade (18.4%), and 3rd grade (15.6%). The lowest representation was from 2nd grade (7.1%). This distribution indicates adequate representation of both genders and all primary grade levels across the study population.

Table 1: Gender and Class Distribution of Participants

Category	Subgroup	Frequency	Percent
Gender	Male	517	51.0
	Female	496	49.0
	Total	**1013**	**100.0**
Class	2nd	72	7.1
	3rd	158	15.6
	4th	253	25.0
	5th	186	18.4
	6th	120	11.8
	7th	224	22.1
	Total	**1013**	**100.0**

Analysis of Tamil script:

The Mann–Whitney U test revealed significant gender differences across all handwriting domains (p = 0.0005), with lower scores indicating better performance. For HPSQ Total Score, boys (Mean Rank = 551.12) scored worse than girls (461.01), U = 105405. For Legibility, boys (555.77) outperformed girls (456.17), U = 103003. Performance Time was higher in boys (542.37) compared to girls (470.13), U = 109928. Physical and Emotional Well-being also favored girls (boys: 547.06; girls: 465.25), U = 107507. These results confirm girls' superior handwriting proficiency and well-being across all domains.

Table 2: Analysis of Tamil Script – Gender Comparison (Mann–Whitney U Test)

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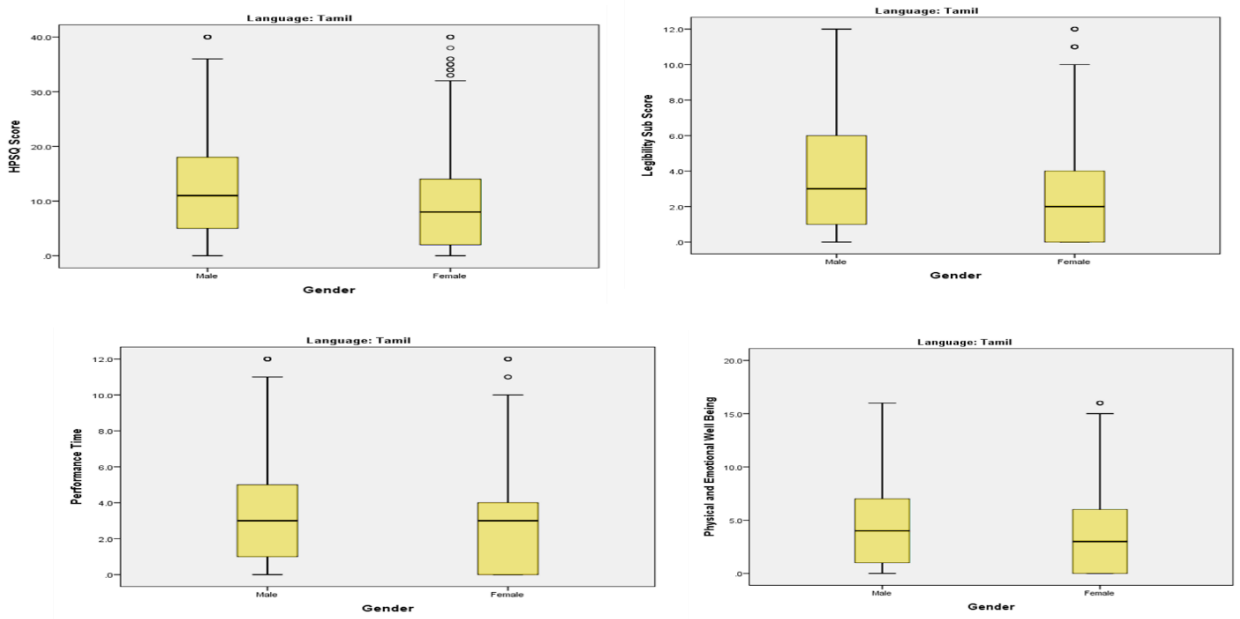
Gender		N	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	p-value
HPSQ Score (n=1013)	Male	517	551.12	284930.00	105405.000	-4.913	.0005
	Female	496	461.01	228661.00			
Legibility Sub Score (n=1013)	Male	517	555.77	287332.00	103003.000	-5.491	.0005
	Female	496	456.17	226259.00			
Performance Time (n=1013)	Male	517	542.37	280407.00	109928.000	-3.969	.0005
	Female	496	470.13	233184.00			
Physical and Emotional Well Being (n=1013)	Male	517	547.06	282828.00	107507.000	-4.493	.0005
	Female	496	465.25	230763.00			

Boxplots comparing Tamil handwriting performance show girls consistently outperform boys across all domains. Girls have significantly lower median scores for HPSQ Total and Legibility Sub-Score, indicating superior proficiency and clarity, while boys display greater variability and outliers. Performance Time differences are smaller, though girls are faster. Physical and Emotional well-being scores favor girls, reflecting lower discomfort and strain. Mann–Whitney U tests confirm these differences as statistically significant ($p < 0.005$), highlighting better overall handwriting performance among girls.



Spearman's analysis showed no significant correlation between age and HPSQ score ($r = 0.015$, $p = 0.623$) or legibility ($r = 0.005$, $p = 0.863$). Age negatively correlated with performance time ($r = -0.090$, $p = 0.004$) and weakly positively with well-being scores ($r = 0.068$, $p = 0.030$).

Table 3 Correlations of age and Tamil script

			HPSQ Score	Legibility Sub Score	Performance Time	Physical and Emotional Well Being
Spearman's rho	Age	Correlation Coefficient	.015	.005	-.090**	.068*
		p-value	.623	.863	.004	.030
		N	1013	1013	1013	1013
**. Correlation is significant at the 0.01 level (2-tailed).						
*.Correlation is significant at the 0.05 level (2-tailed).						

Scatterplots show a slight negative trend for performance time (y = 4.69 - 0.14x, R2 = 0.008) and a weak positive trend for well-being (y = 3.1 + 0.12x, R2 = 0.003), indicating minimal age-related effects.

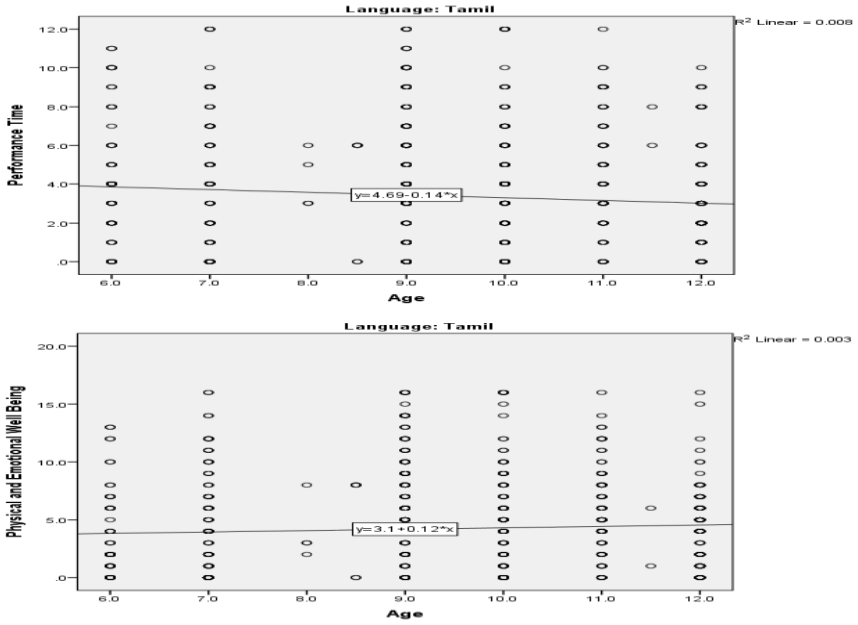
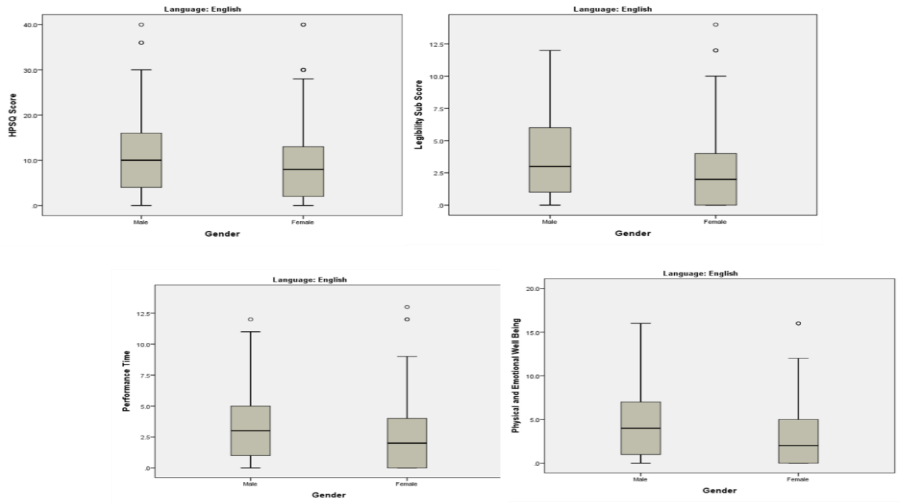


Table 4. Analysis of English script– Gender Comparison (Mann–Whitney U Test)

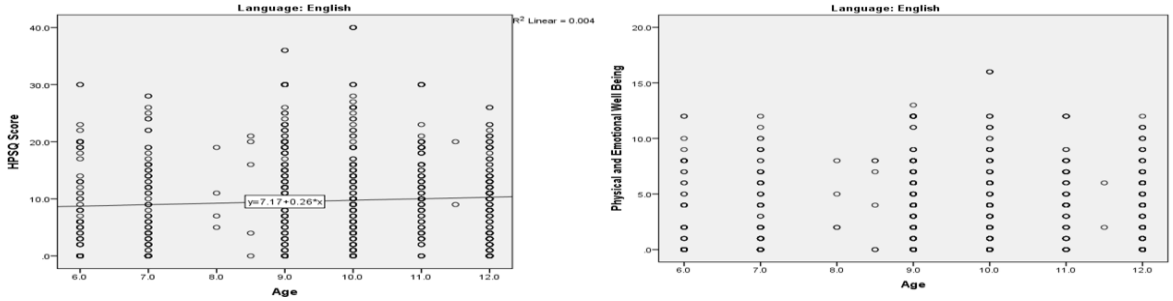
Gender		N	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	p-value
HPSQ Score (n=1013)	Male	517	552.32	285548.00	104787.000	-5.049	.0005
	Female	496	459.76	228043.00			
Legibility Sub Score (n=1013)	Male	517	557.93	288452.00	101883.000	-5.737	.0005
	Female	496	453.91	225139.00			
Performance Time (n=1013)	Male	517	543.34	280905.00	109430.000	-4.091	.0005
	Female	496	469.13	232686.00			
Physical and Emotional	Male	517	544.34	281422.50	108912.500	-4.201	.0005
	Female	496	468.08	232168.50			

Well Being (n=1013)							

Mann–Whitney U tests revealed significant gender differences in handwriting (p = 0.0005). Boys had higher mean ranks than girls in HPSQ total (552.32 vs. 459.76; U = 118,245), legibility (557.93 vs. 453.91; U = 115,894), performance time (543.34 vs. 469.13; U = 124,563), and well-being (544.34 vs. 468.08; U
= 124,062), indicating poorer performance across all domains.



Boxplots for English script show girls significantly outperform boys across all domains (p < 0.005). Girls have lower medians for HPSQ total and legibility, indicating better proficiency and clarity. They also complete tasks faster and report less discomfort, while boys show higher variability, more outliers, and slower performance. These differences highlight consistently superior handwriting among girls.



For English script, age showed a minimal positive correlation with overall HPSQ score (r = 0.068, p = 0.031), indicating slightly poorer proficiency in older children. Legibility (r = 0.034, p = 0.283) and performance time (r = -0.025, p = 0.432) were unaffected by age. However, physical and emotional well- being increased with age (r = 0.129, p = 0.0005), reflecting marginally greater discomfort.

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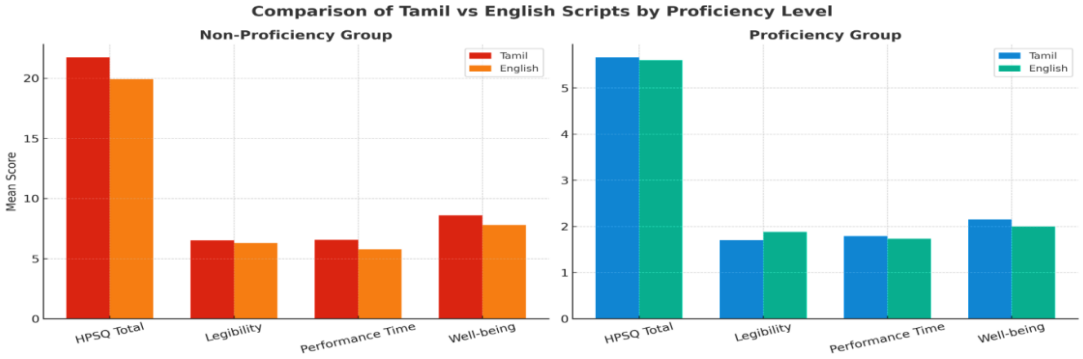
Table 5: Correlations of age and English script

			HPSQ Score	Legibility Sub Score	Performance Time	Physical and Emotional Well Being
Spearman's rho	Age	Correlation Coefficient	.068*	.034	-.025	.129**
		p-value	.031	.283	.432	.0005
		N	1013	1013	1013	1013
**. Correlation is significant at the 0.01 level (2-tailed).						
*.Correlation is significant at the 0.05 level (2-tailed).						

Comparison Between Tamil and English Scripts

Within the Non-Proficiency group, Wilcoxon Signed-Rank Test indicated significantly higher scores for Tamil script compared to English across multiple domains, including HPSQ Total Score ($Z = –8.90$, $p < 0.001$, $r = 0.52$), Performance Time ($Z = –6.80$, $p < 0.001$, $r = 0.40$), and Physical/Emotional Well-being ($Z = –6.50$, $p < 0.001$, $r = 0.38$), suggesting greater difficulty and stress associated with Tamil handwriting. The difference in Legibility was statistically significant but with a small effect size ($Z = –2.60$, $p = 0.009$, $r = 0.15$).

In contrast, within the Proficiency group, differences between Tamil and English were negligible for all domains, with no meaningful effect sizes (all $p > 0.05$), indicating that proficient writers adapt equally well to both scripts.



DISCUSSION

The present study assessed gender differences in handwriting performance among children aged 6–12 years using the Handwriting Proficiency Screening Questionnaire (HPSQ) for both Tamil and English scripts. Regarding Tamil script, findings from the Mann–Whitney U test revealed that girls significantly outperformed boys across all four domains—overall handwriting proficiency, legibility, performance time, and physical/emotional well-being ($p < 0.005$). Boys demonstrated higher mean ranks in every domain, indicating poorer performance, as lower scores represent better handwriting proficiency.

These results align with previous research, which consistently reports superior handwriting skills among girls compared to boys [13, 14]. Girls generally exhibit better fine motor control and visuomotor integration, contributing to improved legibility and faster writing speed [7, 1]. Additionally, gender differences in handwriting may be influenced by neurological maturation, with girls demonstrating earlier development of motor coordination and cognitive skills critical for writing [15].

The observed disparities in physical and emotional well-being scores indicate that boys experience

greater discomfort and strain during handwriting activities. This finding is supported by earlier studies reporting that boys often perceive handwriting as more challenging and less enjoyable [8]. Increased strain may be due to inadequate postural control, slower motor planning, or reduced motivation toward writing tasks[16]. Interestingly, while performance time differences were statistically significant, the effect size was modest.

This suggests that while girls generally write faster, the most pronounced gender gap lies in legibility and overall handwriting proficiency. These findings have practical implications for educational strategies, emphasizing the need for early intervention and targeted motor skill development in boys to prevent handwriting difficulties and associated academic challenges [1, 4]

The boxplots for Tamil script revealed marked differences not only in central tendency but also in the dispersion of scores between boys and girls across all domains. Boys consistently demonstrated a wider interquartile range and the presence of multiple outliers, particularly in the HPSQ Total Score and Legibility Sub-Score, indicating greater variability in handwriting performance. In contrast, girls' scores were more tightly clustered, suggesting higher consistency and stability in handwriting proficiency.

Greater variability among boys aligns with previous findings that report heterogeneity in motor and fine- motor skill development within male populations [13, 14]. Such dispersion may reflect differences in neuromotor maturation, visuomotor integration, and motivation toward writing tasks[7]. Boys' extreme outliers in performance time indicate that while some perform comparably to girls, others require considerably more time, possibly due to lower handwriting automaticity and motor planning efficiency [1]. Similarly, higher variability in physical and emotional well-being scores suggests that boys' handwriting experience ranges from relatively comfortable to significantly effortful, consistent with evidence that boys often report greater task-related strain[8]. The tighter dispersion among girls suggests uniformity in handwriting development, which may be attributed to earlier fine-motor skill acquisition and greater engagement in writing-related activities [15]. Educational research supports the notion that gender-based differences in consistency and speed often emerge in early schooling and persist through primary years[4].Overall, the observed dispersion underscores the importance of targeted interventions, particularly for boys at the lower performance end, to reduce variability and improve handwriting fluency. Discussion on Age and Handwriting Performance (Tamil Script)

The present study found that age had minimal influence on handwriting quality among children aged 6– 12 years. Spearman's correlation revealed no significant association between age and overall handwriting proficiency ($r = 0.015$, $p = 0.623$) or legibility ($r = 0.005$, $p = 0.863$), indicating stability in handwriting quality across the examined age range. This finding aligns with previous research suggesting that handwriting legibility reaches a relatively consistent level by the early primary grades, with subsequent improvements being modest [13, 7]. However, a small but statistically significant negative correlation was observed between age and performance time ($r = -0.090$, $p = 0.004$), suggesting that older children completed handwriting tasks slightly faster. This reflects improved motor automaticity and greater writing fluency with age, consistent with developmental models of handwriting acquisition [1, 8]. As children progress through primary school, they develop better motor coordination and cognitive strategies for efficient handwriting execution[17]. Interestingly, a weak positive correlation was noted between age and physical/emotional well-being scores ($r = 0.068$, $p = 0.030$), indicating that older children reported marginally greater discomfort or emotional strain during handwriting activities. This may be attributed to increased academic demands, extended writing tasks, and higher expectations for handwriting speed and neatness in upper grades[4]. Similar observations have been reported in studies where older students experience greater fatigue and stress during writing tasks[12].

Overall, these findings suggest that age-related improvements primarily affect handwriting speed rather than quality or legibility, while increasing physical and emotional strain could indicate the need for ergonomic and pedagogical adjustments for older children. This study revealed significant gender differences in English handwriting performance, with girls outperforming boys in overall handwriting proficiency, legibility, performance time, and physical/emotional well-being ($p = 0.0005$). Boys exhibited higher mean ranks for HPSQ total score (552.32 vs. 459.76), legibility (557.93 vs. 453.91), and performance time (543.34 vs. 469.13), indicating poorer handwriting quality, slower speed, and increased discomfort. These findings align with prior research demonstrating that girls generally perform better in handwriting tasks [1, 8, 10]. Several factors may account for this disparity. Girls tend to develop fine motor and visuomotor skills earlier, contributing to more fluent and legible handwriting [7,15]. Boys often exhibit slower motor planning and less sustained attention toward handwriting tasks, which can lead to variability and reduced proficiency [6, 16]. Performance time differences, while significant, were less pronounced than differences in legibility and overall proficiency. This suggests that although speed improves with practice, quality gaps persist due to neuromotor and perceptual-motor differences[17, 18]. The higher scores for boys in physical/emotional well-being domains indicate greater strain and effort during handwriting activities, consistent with reports that boys experience more fatigue and discomfort during prolonged writing [6, 19]. Gender-based discrepancies in handwriting proficiency have implications for academic achievement, as handwriting fluency significantly impacts composition and literacy skills[9]. Therefore, targeted interventions such as fine-motor training, posture correction, and structured handwriting practice, particularly for boys, are essential to minimize gaps and enhance writing outcomes[4.] The boxplot analysis for English handwriting performance reveals clear gender differences across all domains of the HPSQ— total score, legibility, performance time, and physical/emotional well-being—with girls consistently outperforming boys. Girls exhibited lower medians and narrower interquartile ranges, indicating superior and more consistent handwriting proficiency. In contrast, boys demonstrated wider dispersion and multiple outliers, reflecting heterogeneous skill levels and, in some cases, significant performance deficits.

Girls generally demonstrate better handwriting proficiency than boys, likely due to earlier development of fine motor and visuomotor skills[1, 15.] Boys show greater variability and poorer consistency, aligning with studies reporting slower writing speeds and irregular letter formation, possibly related to motor planning, endurance, and motivation differences [8, 16, 20].

Legibility differences observed in this study echo prior evidence that handwriting clarity is strongly associated with visuomotor coordination, a domain where girls often exhibit a developmental advantage [6, 17]. Although performance time differences were less pronounced, they favor girls, consistent with literature reporting gender-based fluency advantages [18, 20]. Boys' higher scores in the physical and emotional well-being domain suggest greater fatigue and discomfort during handwriting, an issue linked to ergonomic and biomechanical factors that hinder efficiency [21]. Educationally, these findings reinforce the critical role of handwriting fluency in academic success, apoor handwriting proficiency can constrain composition and literacy skills [9, 22]. Consequently, gender-sensitive interventions—such as targeted fine motor training, ergonomic adaptations, and explicit handwriting instruction—are essential to bridge performance gaps [4, 23].

Tamil vs English Script Comparison The Wilcoxon Signed-Rank Test results indicate that within the non- proficient group, children experienced greater difficulty when writing in Tamil script compared to English across several domains of the HPSQ. Specifically, significantly higher scores for Tamil in the total HPSQ score, performance time, and physical/emotional well-being domains ($Z = –8.90$, $p < 0.001$, $r = 0.52$; $Z = –6.80$, $p < 0.001$, $r = 0.40$; $Z = –6.50$, $p < 0.001$, $r = 0.38$, respectively) suggest that Tamil script imposes higher motor and cognitive demands, resulting in increased discomfort and slower handwriting speed. Although legibility differences

were statistically significant ($Z = –2.60$, $p = 0.009$), the effect size was small ($r = 0.15$), indicating that the primary challenge in Tamil writing relates to fluency and comfort rather than clarity of script formation. This pattern can be attributed to the orthographic complexity of Tamil, an alphasyllabary requiring multi- stroke akshara construction, often involving intricate diacritics and non-linear arrangement of graphemes[24]. These features contrast with the relatively simple and linear structure of English letters, which may explain why Tamil writing is associated with increased performance time and higher physical- emotional strain [25, 26]. The higher motor planning and sequencing requirements in Tamil script likely exacerbate difficulties for children with emerging fine motor skills or handwriting challenges[1].

The negligible differences observed in the proficiency group suggest that once handwriting fluency is mastered, children demonstrate adaptive transfer of motor skills across scripts, consistent with previous cross-linguistic research on bilingual writing [24]. This finding highlights the role of automaticity in motor planning and suggests that interventions should prioritize early development of motor fluency in complex scripts like Tamil to reduce the risk of later academic difficulties [6, 23].

From an educational standpoint, these findings reinforce the importance of script-specific handwriting instruction, particularly for Tamil learners in the early grades. Incorporating multisensory teaching strategies, ergonomic adaptations, and fine-motor strengthening programs could improve fluency and reduce strain [4, 27] . Additionally, early screening using tools like HPSQ can help identify children at risk for handwriting difficulties before they experience academic setbacks.

CONCLUSION

This study found significant gender differences in handwriting for both Tamil and English, with girls outperforming boys across all domains ($p < 0.005$). Boys showed greater variability and discomfort, while age minimally affected quality but correlated with slightly faster speed and higher strain. Tamil script imposed greater motor-cognitive demands than English, highlighting the need for early, script-specific, gender-sensitive interventions and ergonomic strategies, especially for boys and older children, to improve proficiency and reduce handwriting-related stress in multilingual educational settings.

Limitations

The study's limitations include its cross-sectional design, convenience sampling, reliance on subjective teacher reports, exclusion of contextual factors, and focus on only two scripts, reducing generalizability and overlooking multilingual handwriting challenges.

Future Scope

Future research should include longitudinal tracking, multiple scripts, digital handwriting analysis, targeted interventions, psychosocial impact assessment, and teacher-focused strategies to enhance handwriting proficiency and reduce disparities.

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Conflict of interest: None

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