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An Analysis of Chinese Handwriting Performance Among Primary School Students in Macao

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Abstract: *Background*: Handwriting is critically important fo r school-age children in the current education system. Poor handwriting performance during primary school can negatively affect students' academic achievement and self-confidence. *Objectives*: To summarize the average Chinese handwriting performance of local primary school students in Macao using a Smart Handwriting Analysis Platform, identify students at the critical stage of Chinese handwriting difficulties, and understand the concerns of parents and teachers regarding students' Chinese handwriting. *Methods*: A cross-sectional study was conducted from 2019 to 2021. The Smart Handwriting Analysis and Recognition Platform (SHARP) was used to collect and analyze Chinese handwriting performance among 789 typically developing students (Grades 1–6) and 79 students with Special Educational Needs (SEN) in Macao. One-way ANOVA was used to examine differences in Chinese handwriting indicators across grades, and independent-samples t-tests were used to compare performance between typically developing students and SEN students. Parents of participating students completed the Handwriting Ability Checklist (HAC), and homeroom teachers or Chinese language teachers recorded students with handwriting difficulties through additional annotations. *Results*: Chinese handwriting ability among Macao primary school students showed a typical developmental trend. Significant differences were found between typically developing students and SEN students in character boundary exceeding and writing errors. Approximately 9–14% of typically developing students performed at the critical level across SHARP indicators. School teachers paid greater attention to students' writing accuracy. Combining the parent-completed HAC with SHARP results enabled more effective identification of students with Chinese handwriting difficulties. *Conclusion*: The SHARP can assist teachers and occupational therapists in the early identification of students with Chinese handwriting difficulties. By collecting Chinese handwriting performance data from local typically developing and SEN students in Grades 1–6, local norms for Chinese handwriting proficiency among Macao primary school students have been established.

Keywords: Smart handwriting analysis platform; Handwriting difficulties; Primary school students; Chinese handwriting performance; Early identification

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1. Background

Handwriting is critically important for children in the current education system. According to data released by the Education and Youth Development Bureau (DSEDJ) of Macao, the total number of students receiving primary education in the 2024/2025 academic year was 37,245 [1]. In Macao, students begin pre-writing exercises such as sticker pasting and bead threading in kindergarten. Upon entering primary school, time spent on handwriting at school gradually increases, with over 50% of school hours spent on penmanship, including copying and dictation. Children who perform poorly in handwriting during this learning period may experience negative impacts on academic achievement and self-confidence [2,3].

Previous studies have shown that 10–20% of school-age children experience some form of handwriting difficulty [4,5]. Chinese handwriting requires visual discrimination to distinguish stroke forms and positions, as well as spatial organization skills to write clear, well-proportioned characters [3,6]. Therefore, writing speed and accuracy are key indicators of students' performance in Chinese handwriting [7].

Students with different types of Special Educational Needs (SEN) face distinct challenges in learning to write. Students with Attention Deficit Hyperactivity Disorder (ADHD) show lower handwriting legibility and efficiency due to inattention [8]. Students with Autism Spectrum Disorder (ASD) struggle with character formation during writing [9]. In addition, children with Developmental Coordination Disorder (DCD) cannot write fluently due to poor motor coordination [10]. Handwriting difficulties are not typically used as diagnostic criteria for any developmental disorder, but handwriting problems are among the major functional deficits in developmental delay and dyslexia.

Beyond SEN students, typically developing students may also experience handwriting difficulties. A pilot study in November 2019 found handwriting difficulties in some typically developing primary school students. Early assessment is therefore crucial for identifying children with handwriting difficulties. Assessment of Chinese handwriting includes two dimensions: the writing process and the writing product (**Figure 1**). Traditional Chinese handwriting assessments, such as the Tseng Handwriting Speed Test, mainly judge writing speed based on the final product. Process measures include time on paper, time in air, etc., while product measures include error rate and boundary exceeding rate. These indicators are difficult to quantify through clinical observation. With advances in modern technology, computer computing and artificial intelligence enable efficient and accurate assessment of multiple dimensions of students' handwriting performance, which is the main reason for adopting the Smart Handwriting Analysis Platform in this study to collect data on Chinese handwriting performance of Macao primary school students.

Figure 1. Components of Chinese handwriting performance.

2. Research objectives

This study mainly investigated:

(1) The current Chinese handwriting performance of typically developing primary school students across grades in Macao;
(2) The average Chinese handwriting performance and differences between typically developing students and students with Special Educational Needs (SEN);
(3) The number and proportion of typically developing students at the critical stage of handwriting difficulties;
(4) The level of concern of parents and school teachers regarding the Chinese handwriting performance of primary school students.

3. Methods

A cross-sectional design with stratified sampling by region and student population was used. From 2019 to 2021, researchers selected 5 Chinese-medium primary schools and 2 education centers on the Macau Peninsula to assess Chinese handwriting in 789 typically developing students (Grades 1–6) and 79 SEN students. Assessments were conducted by occupational therapists in classrooms at participating schools and centers. Parents of participating students provided informed consent and completed the Handwriting Ability Checklist (HAC) [11]. Thirty homeroom or Chinese language teachers recorded students with handwriting difficulties via annotations, without requiring consent.

3.1. Smart handwriting analysis platform

Assessment of students' handwriting performance is usually product-oriented, with speed and accuracy as core indicators [12]. Earlier computerized handwriting assessment systems mainly analyzed products using preset algorithms [13]. In contrast, the Smart Handwriting Analysis and Recognition Platform (SHARP) (**Figure 2**) uses artificial intelligence to analyze the readability of Chinese characters. Key indicators include incorrect strokes, extra strokes, missing strokes, connected strokes, reversed strokes, and stroke order errors [13,14].

Figure 2. Smart handwriting analysis and recognition platform (SHARP).

SHARP is an objective and accurate cloud-based Chinese handwriting assessment system used to analyze the Chinese handwriting ability of primary school students, help teachers quickly screen those with handwriting difficulties, and support occupational therapists in identifying and understanding students' handwriting problems. Students completed the test at desks equipped with digital tablets and copying templates (**Figure 3**), copying 90 Chinese characters. Assessment data were transmitted via Bluetooth to a cloud platform, which output process and product data (**Figure 4**). Process measures included speed, total

writing time, time in air, time on paper, pen pressure, and standard deviation of time per character. Product measures included stroke errors, extra/missing/connected/reversed strokes, and stroke order errors, analyzed via AI to evaluate performance. SHARP effectively differentiates performance, speed, and error patterns between typically developing and SEN students. Research by the Li-Tsang team confirmed that the platform correlates significantly with core components of handwriting ability: fine motor skills, visual perception, writing process, and character formation [15].

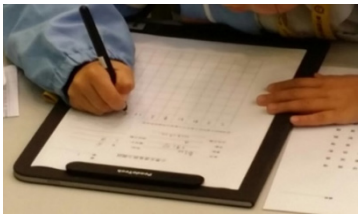

Figure 3. Digital tablet and copying template.

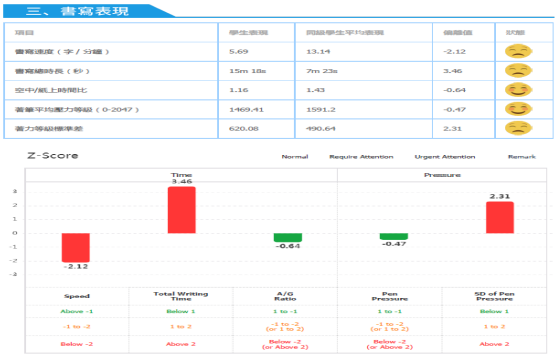

Figure 4. Chinese handwriting process data.

3.2. Inclusion and exclusion criteria

Participants were two groups of students in mainstream schools: typically developing students and SEN students. SEN students were included to compare Chinese handwriting performance with typically developing peers.

3.2.1. Inclusion criteria for typically developing students

(1) Grades 1–6 in mainstream schools;

(2) Proficiency in reading and writing Traditional Chinese.

3.2.2. Exclusion criteria for typically developing students

(1) Physical disability;

(2) Diagnosed neurodevelopmental disorder.

3.2.3. Inclusion criteria for SEN students

Officially identified as having special educational needs by DSEDJ and enrolled in mainstream schools.

3.3. Ethical considerations

Schools were approached to recruit participants, with parental informed consent obtained for all students. To protect privacy, all student data were stored using coded identifiers and registered with the Office for Personal Data Protection of Macao (Ref.: 0737/GPDP/2021). Ethical approval was granted by the Ethics Committee of Yew Chung College of Early Childhood Education (Ref.: 2024/25_ER02-PC03).

3.4. Statistical analysis

Statistical analyses were performed using SPSS 20. Outliers were identified and removed using boxplots. One-way ANOVA compared handwriting indicators across grades among typically developing students. Independent-samples *t*-tests compared typically developing vs. SEN students; non-normally distributed continuous data were analyzed using the Mann–Whitney U test. A p-value < 0.05 was considered statistically significant.

3.5. Sample size calculation for typically developing students

Based on the Hong Kong norm study by Li-Tsang et al. (2013), effect size = 0.2277, $\alpha = 0.05$, power = 0.99 [13]. The study covered Grades 1–6, with 16 indicators analyzed per grade. The required total sample size was 734 students.

4. Results

Only 361 typically developing students were recruited in 2019, insufficient for local norm establishment. Data collection planned for 2020 was suspended due to the COVID-19 pandemic. In 2021, an additional 429 students were assessed. In total, 789 typically developing students and 79 SEN students in Grades 1–6 was included from 2019 and 2021.

4.1. Descriptive statistics for typically developing students

Table 1 presents demographic data (grade, gender, mean age) for 789 typically developing students and 79 SEN students.

Table 1. Demographic characteristics of typically developing and SEN students

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
Male n (%)	TD:109 (55), SEN: 11 (73)	TD: 67 (52), SEN: 13 (76)	TD: 111 (58), SEN: 17 (89)	TD: 53 (59), SEN: 13 (86)	TD: 31 (39), SEN: 5 (100)	TD: 44 (49), SEN: 6 (75)
Female n (%)	TD: 91 (45), SEN: 4 (27)	TD: 63 (48), SEN: 4 (24)	TD: 82 (42), SEN: 2 (11)	TD: 37 (41), SEN: 2 (14)	TD: 55 (61), SEN: 0 (0)	TD: 46 (51), SEN: 2 (25)
Mean age	TD: 6y8m, SEN: 7y	TD: 7y11m, SEN: 7y8m	TD: 8y8m, SEN: 8y7m	TD: 9y10m, SEN: 10y6m	TD: 11y1m, SEN: 11y3m	TD: 12y2m, SEN: 12y

One-way ANOVA revealed significant differences across grades for all indicators *except* stroke order errors (**Table 2**). Writing speed increased with grade, while writing time, boundary exceeding, and errors decreased.

Table 2. Chinese handwriting performance of typically developing students (Grades 1–6) in Macao

Measure	G1 mean (SD)	G2 mean (SD)	G3 mean (SD)	G4 mean (SD)	G5 mean (SD)	G6 mean (SD)	*p*
Writing process							
Speed (char/min)	5.50 (1.64)	7.70 (2.57)	10.15 (2.53)	13.67 (3.13)	16.18 (3.78)	17.15 (3.34)	< 0.0001***
Total time (s)	1060.86 (314.94)	769.33 (249.48)	563.14 (151.34)	415.83 (97.44)	348.44 (81.80)	322.76 (59.25)	< 0.0001***
Time in air (s)	642.75 (204.71)	457.58 (161.72)	329.00 (103.09)	229.75 (63.57)	205.44 (62.23)	189.76 (47.82)	< 0.0001***
Time on paper (s)	402.10 (125.85)	307.56 (115.87)	239.69 (90.37)	182.68 (48.48)	145.77 (33.56)	135.15 (27.98)	< 0.0001***
Air/Paper ratio	1.67 (0.54)	1.55 (0.49)	1.44 (0.40)	1.30 (0.34)	1.40 (0.32)	1.42 (0.33)	< 0.0001***
Pen pressure	1578.27 (248.50)	1586.89 (263.05)	1595.09 (258.00)	1600.66 (246.75)	1512.66 (264.15)	1446.47 (298.81)	< 0.0001***
Pen pressure SD	501.53 (68.66)	486.21 (67.61)	477.35 (65.59)	475.20 (62.76)	478.12 (50.05)	460.90 (50.20)	< 0.0001***
Time per char SD	6.57 (2.66)	4.54 (2.29)	3.13 (1.25)	2.07 (0.68)	1.75 (0.63)	1.47 (0.47)	< 0.0001***
Result of writing							
Boundary exceeding	28.93 (20.22)	21.18 (18.30)	20.43 (18.93)	18.53 (17.04)	8.63 (9.75)	6.69 (9.83)	< 0.0001***
Extra strokes	12.86 (7.03)	11.55 (6.92)	9.31 (6.24)	7.17 (5.32)	5.39 (4.11)	3.78 (2.88)	< 0.0001***
Connected strokes	4.06 (2.97)	4.92 (3.85)	5.92 (4.74)	6.79 (5.57)	6.59 (5.95)	6.33 (4.71)	< 0.0001***
Missing strokes	2.49 (2.39)	2.72 (2.44)	2.92 (2.93)	3.60 (2.87)	3.40 (3.08)	3.73 (2.94)	0.0012**
Reversed strokes	0.61 (0.89)	0.75 (0.99)	0.55 (0.83)	0.66 (2.03)	0.33 (0.62)	0.44 (0.72)	0.0026**
Stroke errors	10.84 (7.26)	10.09 (6.69)	8.08 (5.23)	7.98 (6.38)	6.27 (4.86)	5.71 (3.86)	< 0.0001***
Stroke order errors	4.79 (2.36)	5.17 (2.47)	4.73 (2.33)	4.81 (1.94)	4.48 (2.48)	4.87 (2.78)	0.43
Total errors	36.64 (14.35)	36.25 (14.24)	32.15 (13.18)	31.32 (15.46)	27.00 (12.96)	25.52 (10.26)	< 0.0001***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Total errors include stroke errors, extra/missing/connected/reversed strokes, and stroke order errors.

4.2. Comparison between typically developing and SEN students

Significant differences varied by grade (**Table 3**). Grade 1 showed differences in 7 measures; Grade 2 in pen pressure SD and boundary exceeding; Grades 3–4 in accuracy; Grade 5 in 3 measures; Grade 6 in 5 measures.

Table 3. Group differences (*p*-values) between typically developing and SEN students by grade

TD/SEN	G1	G2	G3	G4	G5	G6
Chinese writing process Average writing speed	0.78	0.59	0.76	0.69	0.60	0.011*
Average writing speed	0.43	0.61	0.64	0.47	0.82	0.0033**
Average time in the air	0.018*	0.53	0.93	0.73	0.97	0.09
Average time on paper	0.56	0.77	0.43	0.15	0.79	0.06
Average ratio of time in the air to time on paper	0.02*	0.18	0.65	0.10	0.51	0.80
Average pressure of writing	0.98	0.31	0.06	0.46	0.20	0.18

Average standard deviation of pressure of writing	0.26	< 0.0001***	0.89	0.27	0.84	0.39
Average standard deviation of time per character	0.33	0.23	0.58	0.07	0.87	0.96
Chinese writing result Average deviation of going off the line	0.0024**	0.0001***	< 0.0001***	0.0017**	0.14	0.0021**
Average number of additional strokes	0.55	0.31	0.56	0.74	0.20	0.27
Average number of connected strokes	0.0051**	0.011*	0.06	0.0176*	0.039*	0.84
Average number of omitted strokes	0.0014**	0.08	0.025*	0.010*	0.0086**	0.06
Average number of reversed strokes	0.92	0.45	0.73	0.48	0.09	0.38
Average number of stroke errors	0.036*	0.26	0.0005***	0.022*	0.52	0.026*
Average number of stroke sequence errors	0.99	0.79	0.66	0.15	0.60	0.56
Average number of writing errors	0.044*	0.11	0.0099**	0.033*	0.044*	0.028*

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

4.3. At-risk (critical) students

Students whose handwriting performance indicators fell between +1 to +2 SD or −1 to −2 SD were defined as at-risk (critical) handwriting difficulty students. These students are usually difficult to identify in daily school life; their handwriting is often characterized by slow speed and high error rates. The SHARP system can effectively identify such students.

Data from the 789 primary school students in this study (shown in **Table 4**) revealed that approximately 9–14% of students performed at the critical level across SHARP indicators. Among them, the number of at-risk students was relatively high in writing speed (105 students, 13%), pen pressure SD (108 students, 14%), and total errors (110 students, 14%). In contrast, fewer students were at risk in time on paper (78 students, 10%) and time per character SD (70 students, 9%). The percentage distribution by grade is shown in **Figure 5**.

Table 4. Distribution of at-risk typically developing students (Grades 1–6)

Measure	G1	G2	G3	G4	G5	G6	Total	%
Sample size	200	130	193	90	86	90	789	—
Writing process								
Speed (−1 to −2 SD)	26	14	30	14	12	9	105	13%
Total time (+1 to +2 SD)	22	14	21	10	10	7	84	11%
Time in air (+1 to +2 SD)	22	17	17	12	6	8	82	10%
Time on paper (+1 to +2 SD)	20	10	17	11	12	8	78	10%
Pen pressure SD (+1 to +2 SD)	26	16	25	15	12	9	108	14%
Time per char SD (+1 to +2 SD)	21	11	14	12	9	3	70	9%
Writing product								
Boundary exceeding (+1 to +2 SD)	36	15	25	12	10	3	101	13%
Total errors (+1 to +2 SD)	30	16	27	15	8	14	110	14%

Note: Total errors include stroke errors, extra strokes, missing strokes, connected strokes, reversed strokes, and stroke order errors.

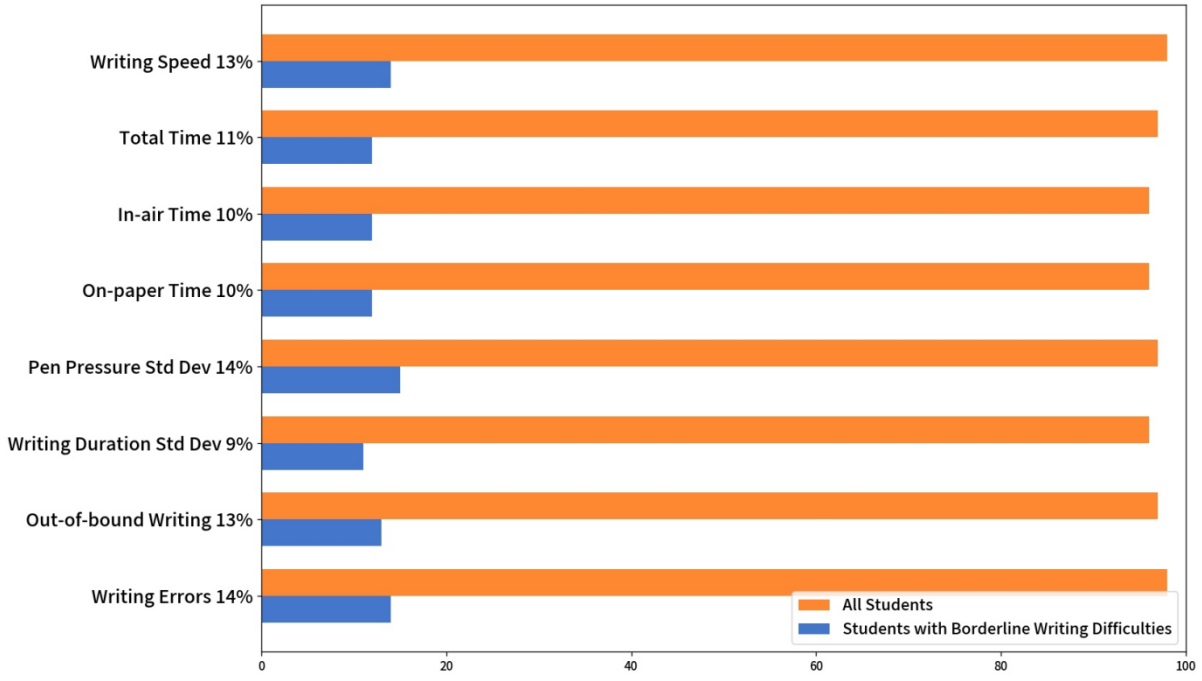

Figure 5. Percentage of at-risk typically developing students (Grades 1–6) in Chinese handwriting performance.

4.4. Parent-completed HAC vs. SHARP indicators

To evaluate parents' understanding of their children's Chinese handwriting performance, this study analyzed the Handwriting Ability Checklist (HAC) completed by parents of Grades 1–6 students from 5 schools and 1 education center. The screening criterion was: questionnaires with 3 or more unanswered items out of 10 were excluded.

Following the criterion of Tam (2008), a total score of 30 was used as the cutoff to screen for handwriting difficulties [11]. Students scoring ≥ 30 were identified as needing close attention from parents, teachers, and occupational therapists. Since no Grade 6 students scored ≥ 30, this grade was excluded from subsequent comparative analysis.

Finally, typically developing students in Grades 1–5 was divided into two groups:

(1) HAC < 30 (no special attention needed)

(2) HAC ≥ 30 (needs special attention)

The demographic distribution and valid response rates are shown in **Table 5**.

Table 5. Demographics of students with HAC < 30 vs. HAC ≥ 30

Group	G1	G2	G3	G4	G5	G6
At-risk (HAC ≥ 30)	19	12	21	8	7	0
Not at-risk (HAC < 30)	176	117	168	79	78	89
Total	195	129	189	87	85	89
Response rate (%)	98	99	97	96	98	99

Analysis in **Table 6** shows significant differences in some handwriting indicators between the two HAC groups:

Grade 2: significant difference in boundary exceeding ($p < 0.01$)

Grade 3: significant difference in time per character SD ($p < 0.05$)

Grade 4: significant differences in speed, total time, time per character SD, and total errors

Grade 5: significant difference only in total errors ($p < 0.001$)

Table 6. Differences in Chinese handwriting performance: HAC < 30 vs. HAC ≥ 30

SHARP measure	Group	G1 p	G2 p	G3 p	G4 p	G5 p
Speed	HAC < 30 / ≥ 30	0.57	0.76	0.23	0.046*	0.16
Total time	HAC < 30 / ≥ 30	0.78	0.43	0.27	0.03*	0.15
Time per char SD	HAC < 30 / ≥ 30	0.53	0.67	0.014*	0.003**	0.34
Boundary exceeding	HAC < 30 / ≥ 30	0.66	0.008**	0.40	0.77	0.82
Total errors	HAC < 30 / ≥ 30	0.15	0.077	0.22	< 0.0001***	< 0.0001***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Note: Total errors include stroke errors, extra strokes, missing strokes, connected strokes, reversed strokes, and stroke order errors.

4.5. Teacher-annotated handwriting problems vs. SHARP indicators

This section included typically developing students in Grades 1–6 from 5 schools. Students identified by teachers as having handwriting difficulties were compared with those not identified. To ensure objectivity, classes without teacher annotations were excluded. The numbers of annotated and non-annotated students by grade are shown in **Table 7**.

Table 7. Demographics of students with/without teacher-annotated handwriting problems

Group	G1	G2	G3	G4	G5	G6
Teacher-annotated	34	19	9	12	14	8
Not annotated	106	83	74	62	72	78
Response rate (%)	70	78	43	82	100	96

As shown in **Table 8**, total errors differed significantly between annotated and non-annotated students from Grade 1 ($p < 0.001$) to Grade 4 ($p < 0.05$).

Speed and boundary exceeding also differed significantly in Grades 2, 3, and 4.

Table 8. Differences in Chinese handwriting performance: annotated vs. non-annotated

SHARP measure	Group	G1 p	G2 p	G3 p	G4 p	G5 p	G6 p
Speed	Annotated / Not	0.65	0.18	0.0016**	0.29	0.35	0.85
Total time	Annotated / Not	0.58	0.19	0.096	0.28	0.45	0.82
Time per char SD	Annotated / Not	0.15	0.05	0.20	0.086	0.36	0.99
Boundary exceeding	Annotated / Not	0.29	0.0005***	0.12	0.013*	0.20	0.99
Total errors	Annotated / Not	0.0015**	0.0074**	0.008**	0.049*	0.12	0.20

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Note: Total errors include stroke errors, extra strokes, missing strokes, connected strokes, reversed strokes, and stroke order errors.

5. Discussion

5.1. Statistical norms for Macao mainstream and SEN students

The Hong Kong norm study reported an effect size of 0.2277. The present study covered 6 grades (Grades 1–6) with 16 indicators per grade [13]. To achieve 99% power and 5% Type I error, a priori GPower analysis required a total sample of 734 students. The 789 mainstream students collected in 2019 and 2021 exceeded this requirement, confirming the sample was statistically sufficient to establish local Chinese handwriting norms.

Consistent with Hong Kong students, Macao students showed increased writing speed and decreased total time and errors with grade level [13].

ANOVA showed no significant improvement in stroke order errors across grades, indicating persistent stroke order problems. Since stroke order supports character learning transfer and efficiency, the SHARP system's ability to detect this issue warrants further research and intervention.

In discriminant validity analyses, the 79 SEN students showed significant differences from mainstream students in speed, total time, time in air, boundary exceeding, connected strokes, missing strokes, stroke errors, and total errors across grades. Grade 1 SEN students showed more deficits than higher grades. No single indicator was consistently significant across all grades, reflecting the heterogeneous difficulties of SEN students. Overall, SEN students' weaknesses were concentrated in product outcomes such as stroke and boundary errors.

5.2. The role of occupational therapists for handwriting difficulties (including at-risk students)

Mainstream and SEN students differed significantly in boundary exceeding, connected strokes, missing strokes, stroke errors, and total errors. SEN students showed particular deficits in boundary control and stroke formation. Although SEN students improved with age, they still did not reach same-age standards [16]. SHARP measures help identify underlying factors affecting their handwriting.

SEN students' poor performance in strokes and boundaries likely reflects visual-perceptual and upper-limb coordination deficits, which can be further evaluated by occupational therapists through hand function, visual perception, and oculomotor assessments.

Among the 789 mainstream students, an average of 92 students (12%) were at-risk, consistent with previous literature (6–37%) [17,18] . These students are often overlooked and mislabeled as inattentive. Early identification and group training can effectively improve their handwriting.

Occupational therapists can provide interventions not only for students below average but also for at-risk students. Evidence shows appropriate school-based interventions improve handwriting [19,20]. Thus, occupational therapists play a key role in early screening, identification, and intervention for both below-average and at-risk students.

5.3. HAC and parental concerns about handwriting

The HAC was used to examine whether parental ratings matched objective SHARP measures. Students were split into "parental concern" and "no concern" groups and compared on speed, total time, SD, boundary exceeding, and errors.

For Grades 4–5, significant differences appeared in speed, total time, time per character SD, and total errors, indicating parents of older students judged handwriting objectively. This aligns with developmental

trends: speed increases in lower grades but stabilizes in Grades 4–6 [14]. Interventions for older students may include task and assessment accommodations [21].

For younger grades, only boundary exceeding (Grade 2) and time per character SD (Grade 3) differed significantly. This gap likely reflects limited parental knowledge of early handwriting development or overly high expectations, leading to subjective ratings. Combining HAC with SHARP provides a more comprehensive profile. Occupational therapy evaluation can support individualized intervention plans to improve skills and confidence.

5.4. Teachers play an important role in identifying at-risk students

About 30 homeroom or Chinese teachers annotated students with handwriting difficulties. Significantly higher total errors were found in annotated students in Grades 1–4, showing teachers accurately identified accuracy deficits in early grades.

Beyond classroom observation, SHARP provides objective data on time in air, time on paper, and pen pressure to help teachers identify difficulties earlier. Teachers can then provide in-class support or refer to occupational therapists for further assessment and intervention.

5.5. Limitations and future recommendations

The sample size of the SEN group was unbalanced relative to mainstream students. According to DSEDJ (2025), among 37,245 students aged 6–11 in 2024/2025, only 382 (around 1%) were SEN. SEN students in Grades 5–6 was fewer than in Grades 1–4 [1]. Future studies should recruit more SEN students to strengthen comparisons.

The COVID-19 pandemic severely disrupted education from December 2019 [22,23]. Remote and hybrid learning were widely adopted. In Macao, face-to-face classes were suspended for nearly four months in 2020. Chinese handwriting relies heavily on in-person guidance; remote learning likely reduced performance. Thus, the 2019–2021 combined averages should be interpreted cautiously, as pandemic-related school closures may have lowered 2021 scores.

5.6. Clinical applications

Combining the parent/teacher HAC with SHARP results:

If key indicators (speed, total errors) exceed ± 2 SD, individualized intervention and comprehensive assessment are recommended to identify core causes.

If indicators fall between ± 1 and ± 2 SD, group intervention is suggested to address underlying issues and provide ongoing monitoring.

6. Conclusion

The cloud-based Smart Handwriting Analysis and Recognition Platform (SHARP) assesses Chinese handwriting difficulties and enables early identification. By collecting data from mainstream and SEN students in Grades 1–6, local norms for Macao primary school students have been established. These norms allow teachers and occupational therapists to quickly screen for handwriting difficulties, identify underlying causes, and deliver early intervention.

Disclosure statement

The authors declare no conflict of interest.

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