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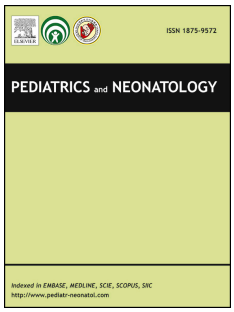

Higher Risk for Poor Handwriting in Taiwanese Children Born Late Preterm

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23 Declarations of interest: none.

24

Abstract

Background

Late-preterm and early-term births constitute a significant proportion of live births. However, handwriting skills of these two populations remain unclear. We aimed to investigate their risk for poor Chinese handwriting in grade two.

Methods

In this observational study, 185 second graders born late preterm (34^{+0}–36^{+6} weeks' gestation, n = 54), early term (37^{+0}–38^{+6} weeks' gestation, n = 56), and full term (39^{+0}–41^{+6} weeks' gestation, n = 75) without any intervention or diagnosis related to developmental delays were included. Their handwriting performance was rated by class teachers using the Chinese Handwriting Evaluation Form (CHEF), which is a standardized handwriting scale including five handwriting dimensions (construction, accuracy, directionality, speed, and pencil grasp).

Results

After controlling for demographic risk factors, the late-preterm born group had a greater risk of having worse performance in the full form (adjusted odds ratio [aOR] = 3.93; p = .038) and construction dimension (aOR = 4.77; p = .009) of the CHEF than peers born at full term, whereas the risks were comparable for the early- and full-term born groups (aOR = .14 – 1.90; p = .073 – .453 in the handwriting dimensions).

Conclusions

Late-preterm but not early-term born children were found to be at higher risk for poor

Chinese handwriting in grade two. They particularly have difficulty with spatial construction including size, spacing, and alignment of Chinese characters and components that may influence handwriting legibility.

Key Words: late preterm; early term; handwriting; grade two

Introduction

Late-preterm (34^{+0}–36^{+6} weeks' gestation) and early-term births (37^{+0}–38^{+6} weeks' gestation) respectively constitute 3–6% and 15–31% of single live births across high-income countries.[1] The combined birth rate of the two abovementioned infant populations is second only to that of full-term births (39^{+0}–41^{+6} weeks' gestation).[2] Due to the significant proportion of late-preterm and early-term births, it is important to understand the effects of these near-term births on developmental outcomes.

Over recent decades, studies have shown that being born a few weeks early increases the risk for adverse developmental outcomes.[3] Population-based studies have consistently indicated that late-preterm and early-term born infants and preschoolers are at a slightly but significantly increased risk of having neurodevelopmental delays.[4,5] For instance, compared to the reference group born at full term, the range of odds ratio (OR) for developmental delay risk was shown to be 1.4–2.6 for late-preterm and 1.2–1.6 for early-term born children, respectively.[4,5] Therefore, more children born late preterm (23.5%) and early term (14.9%) require early intervention as compared to their full-term born peers (11.9%).[6] Those children born near term were found to continue to perform poorly; they had increased need of special educational support and they scored lower in various academic subjects (reading, math, literacy, and writing) compared to their peers born full term.[7–10] However, school functioning in these children has not been fully investigated. For example, little is known about their

handwriting function in the literature.

Proficient handwriting is an essential academic skill. Elementary school children particularly in first grades spend a lot of time learning handwriting.[11] Even so, some children encounter handwriting difficulties, including illegible handwriting and slow writing speed.[12,13] In terms of the results of factor analysis, studies have further identified four legibility-related factors (letter formation, spacing, alignment and size) in the alphabetic system[14] and three factors (construction, accuracy and directionality) in the Chinese system.[12] The problems in the construction factor consist of inappropriate size, spacing, and alignment of Chinese characters and components. The malformations of characters (e.g., adding or missing strokes) belong to the category of accuracy problems. The directionality problems consist of upside down or reversed components shown in Chinese characters.[12,15,16] The three factors can be separately investigated when examining a child's Chinese handwriting legibility problems.[12,15]

Studies investigating handwriting performance of children born prematurely are limited.[17–19] Also, most studies focused on children born at less than 34 weeks of gestation (i.e., very and moderate preterm born).[17,18] Researchers have found that these children have poorer letter and word legibility and slower writing speed compared with term born classmates in the assessment of the Evaluation Tool of Children's Handwriting-Manuscript.[17] Similarly, in terms of teacher's rating, more were rated as performing at below average or

very poor levels in handwriting than their peers born at term.[17,18] However, it is uncertain whether this impact of preterm birth on handwriting performance also extends to children born at beyond 34 weeks of gestation.

To fill the knowledge gap, there are three aims in this study. First, we compared the risk of having handwriting difficulties in children born late preterm, early term, and full term using a standardized, multi-dimensional Chinese handwriting questionnaire. Secondly, difficulties in specific handwriting dimensions of the three groups were examined. In addition, we also investigated the relationship between sociodemographic factors (i.e., child's age and sex, maternal education) and handwriting difficulties.

Methods

Participants

This study was a part of a large project related to the handwriting performance of second graders born at different gestational weeks. The project was conducted from November 2015 to May 2017. The children's handwriting performance was evaluated in the second semester of the second grade using the Chinese Handwriting Evaluation Form (CHEF).[16]

In this project, there were two methods to recruit preterm children born below 37 weeks of gestation. One was to invite the parents of preterm children who were registered in the preterm baby registration records of a medical center in Tainan to participate in the study by

telephone. The other method was to recruit preterm children through a research leaflet given to the parents of second graders attending elementary schools in Tainan. Children born at or more than 37 weeks of gestation were recruited from the second grades of elementary schools in Tainan, Taiwan. If the class teachers agreed to participate, they were asked to give our research package including study proposal, written informed consent, and demographic questionnaire to the parents of five randomly selected children in their class on our behalf. The detailed procedure for the data collection in this project was described in a study by Shih et al.[19]

An observational study design was used for the present study. For the purpose of this study, children born at 34^{+0} – 41^{+6} weeks of gestational age (GA) with native Chinese-speaking parents were analyzed. The exclusion criteria included the following: (1) congenital anomalies; (2) genetic or chromosome abnormalities; (3) auditory and visual problems that cannot be corrected to a normal range; (4) a diagnosis of neurodevelopmental disorders (e.g., cerebral palsy, attention deficit hyperactivity disorder, autism spectrum disorder, and intellectual disabilities); (5) a history of early intervention related to developmental delays; or (6) injuries in the neuromuscular system of the trunk or upper extremities that may affect handwriting performance. Information regarding the exclusion criteria was obtained from the demographic questionnaire filled out by parents. Then, according to the child's gestational weeks at birth, participants were classified into late-preterm, early-term, and full-term born

groups.

Measures

Chinese Handwriting Evaluation Form (CHEF)

The CHEF is a standardized, norm-referenced, teacher-reported handwriting questionnaire developed by Taiwanese researchers to detect handwriting difficulties in first and second graders.[16] A total of 25 item questions describing problematic performance in five dimensions (construction, accuracy, speed, pencil grasp, and directionality) were rated by the child's class teacher using a 5-point Likert scale (1: never matching to 5: always matching). Eight items in the construction dimension are related to problems in size, spacing, and alignment of Chinese characters and components. Five items in the accuracy dimension relate to the malformation of characters (i.e., incorrect configuration of components, adding or missing strokes), incorrect stroke sequence, and poor literacy grades. Two items in the directionality dimension were used to identify problems where the character components are upside down or reversed. The performance in the abovementioned three dimensions influences handwriting legibility. Four items in the speed dimension consist of slow writing speed, inattention to handwriting tasks, messiness shown on the homework or test sheets, and failure to finish handwriting tasks on time. The pencil grasp dimension includes six items describing problematic biomechanical characteristics of pencil grasp (e.g., pencil tip pressure on paper, tight grip). A higher score means poorer handwriting performance. A cut-off percentile of 15% indicates

159 " handwriting difficulty" , as suggested by the test manual on the basis of the norm of 468
160 first (n = 243) and second (n = 119) graders.[16]

161 The psychometric properties of the CHEF have been examined and provided in the test
162 manual.[16] Its internal consistency (Cronbach α = .70–.93), test-retest reliability (r = .79–.90),
163 and split-half reliability (r = .64–.98) are acceptable to good. The discriminative validity of
164 the CHEF has been proven in children with typical handwriting and in those having difficulty
165 with handwriting. The concurrent validity of the CHEF and the handwriting Battery of
166 Chinese Basic Literacy subscales has been validated. The inter-rater reliability has not been
167 established by the developers.[16] There is only one class teacher for each class in Taiwanese
168 elementary schools, who teach all literacy and mathematic courses.[16] Thus in this study, we
169 established the inter-rater reliability of the CHEF by asking 14 mothers who knew their
170 child's handwriting performance well (i.e., the mothers rating 7–10 points in the scale of
171 familiarity with the child's handwriting performance using a 10-point Likert scale) to fill out
172 the CHEF simultaneously. Significantly strong correlations between the teachers' and
173 mothers' ratings in all dimensions (r = .75–.89, $p \leq .01$) and full form (r = .90, $p < .001$) of
174 the CHEF indicated that the CHEF has good-excellent inter-rater reliability except for the
175 pencil grasp dimension (r = .53, p = .093).

176 **Sociodemographic Questionnaire**

177 This self-designed questionnaire consists of questions about the child's birth and medical

history, handedness, and maternal age and education. Mothers were asked to fill out this questionnaire.

Procedure

Parents who agreed to participate in this study were asked to fill out the demographic questionnaire. Then their child's class teachers were invited to participate in this study. Teachers were asked to observe the target child's handwriting performance and then complete the CHEF and return it to the first author by mail. To avoid bias, teachers were blind to student's birth history.

Data Analysis

Depending on the type of data (continuous or categorical), one-way analysis of variance (ANOVA) or chi-squared method was used to compare the demographic characteristics of the three gestational age groups (late preterm, early term, and full term). The adjusted odds ratio (aOR) and 95% confidence interval (CI) of poor handwriting for the two near-term born groups with full-term birth group as the reference group were estimated using multivariate logistic analysis. The logistic analysis was also used to examine the independent contribution of child's age and sex and maternal education to the risk of having poor handwriting. All analyses were conducted using SPSS 17.0 software (SPSS Inc. Chicago, IL, USA). The statistical significance was set as $p < .05$ in all analyses.

Results

Child's characteristics

The data of 185 children (late preterm: 54, early term: 56, and full term: 75) meeting the criteria were included in the analysis. Their demographic characteristics are described in Table 1. There was a significant difference in gestational age ($p < .001$), birthweight ($p < .001$), and maternal educational levels ($p = .016$) among the three groups. A greater percentage of mothers in the late preterm group (73.7%) had higher educational levels (i.e., completing college/university or higher degrees) as compared to the early-term (47.3%) and full-term (57.3%) groups. No group differences were found in the children's chronological age, sex, handedness, or maternal age.

Poor Chinese Handwriting in the Gestational Age Groups

The proportion of late preterm born children with poor performance in various handwriting dimensions seemed to be higher than their peers born at full term, particularly in the full form (18.5% vs. 5.3%) and the construction dimension (25.9% vs. 6.7%) (Table 2). In contrast, there was a similar proportion of children with poor handwriting in each dimension and the full form in the groups born early term and full term (Table 2). After controlling for potentially confounding factors (i.e., child's age and sex, and maternal education), the logistic results indicated that children born late preterm had a higher risk of having poor handwriting

in the full form (aOR = 3.93; p = .038) and the construction dimension (aOR = 4.77; p = .009) as compared to those born at full term. The adjusted risk of having poor handwriting for early- and full-term born children was not significant (Table 3).

Demographic Characteristics and Poor Handwriting Performance

The results of the multivariate logistic regression indicated that the child's age, sex, and maternal education independently contributed to the performance in specific handwriting dimensions (Table 3). Every additional month of age significantly decreased the risk of poor performance in the dimensions of accuracy (aOR = 0.81; p = .013) and directionality (aOR = 0.80; p = .004), and the full form (aOR = 0.81; p = .013) of the CHEF to a small degree. Boys were at significantly greater risk for poor performance in the dimensions of construction (aOR = 7.03; p = .002) and accuracy (aOR = 4.78; p = .015) and the full form (aOR = 5.56; p = .009) than girls. In addition, children of mothers who had below college/university education were at higher risk of having poor performance in the accuracy dimension (aOR = 6.94; p = .003) (Table 3).

Discussion

Our results showed that after controlling for the child's age, sex, and maternal education, the risk of poor handwriting for late-preterm born children was approximately fourfold as high as

their full-term peers in the second grade. To our knowledge, this was the first study to investigate the handwriting performance of children born late preterm. The present findings on handwriting performance were consistent with the previous findings, which indicated that the late-preterm birth born population were still at a higher risk for poor developmental outcomes than those born at term.[4,5] However, our findings were slightly different from Feder et al's findings on handwriting performance of 42 first graders born below 34 weeks of gestation, who demonstrated the problems of poorer word, letter, and numeral legibility (Cohen's d: 0.34–0.67, medium effect size [ES]) and slower near- and far-point copying speed (Cohen's d: 0.74–0.89, large ES) than their 42 peers born at term.[17] Compared to the peers born at full-term, our late-preterm participants studying in the second grade had handwriting difficulty, particularly in the dimension of Chinese character construction (Cramer's V: 0.27, medium ES), one component of legibility. Both studies may conclude that preterm births have a moderately adverse effect on children's handwriting legibility in the first grades. However, unlike Feder et al's study, we did not find that children born late preterm had significantly slower writing problems than their peers. This inconsistent result between the studies may be attributed to the difference in gestational weeks at birth and studying grades. As expected, earlier preterm births generally lead to more adverse impacts on brain development[20] and developmental outcomes.[9] Additionally, one study has indicated that handwriting performance continues to improve even by the third grade of elementary

school.[21] Thus, the slow writing speed shown in preterm children may quickly improve from the first to second grade.

Our results demonstrated that even in the absence of a history of developmental delays after birth, nearly 20% of late-preterm children were identified as having poor handwriting. This finding implies that some mild deficits in late-preterm children may be not discovered until they are required to complete complicated tasks (e.g., handwriting) when they are older. Future studies are required to further investigate the relationship between early medical factors and poor handwriting to define the high-risk subgroup born late preterm. On the other hand, a long-term, comprehensive developmental follow-up program may be required for them to prevent later difficulties in school performance.

As mentioned above, the late-preterm children particularly had difficulty with spatial construction of Chinese characters and components, including spacing, size, alignment, and slant, which may lead to handwriting illegibility. Previous studies have demonstrated that visual perception,[17] attention,[19] tactile and kinesthetic perceptions,[22] visuomotor integration,[23,24] in-hand manipulation (i.e., translation and rotation of a small peg within one hand), and motor coordination (i.e., tracing the forms by connecting dots within provided paths)[24] are significant factors related to handwriting legibility. Future research is needed to examine the relationships among these potentially underlying factors and the poor character construction in late-preterm children to provide a guide for supportive intervention for their

handwriting problems. On the other hand, one meta-analysis study has indicated that in the alphabetical language system, the use of a digitizing tablet for copying letters and self-evaluation (i.e., students evaluate the quality of their handwriting compared to the models or with transparent overlays) as part of handwriting instruction can improve students' handwriting legibility.[25] However, there is little evidence of improving the legibility or construction of children's Chinese words. Whether the interventions used in the alphabetical language system also enhance the Chinese character construction of children born late preterm needs further investigation.

Regarding developmental outcomes of children born early term, previous studies have indicated that they have a slightly increased risk of developmental (e.g., language and cognitive problems) and school performance problems (e.g., lower academic achievement) than their peers born at full term.[5,7,8] However, we did not find such a difference between early-term and full-term children in terms of their handwriting quality. Since no previous study has explored the handwriting of early-term born children, the current findings cannot be compared to earlier results. The absence of a significant difference between these early- and full-term groups in our study may be in part a result of a higher ratio of 38 weeks' to 37 weeks' gestation in our early-term group (4.6:1). The ratio of 38 weeks' to 37 weeks' gestation shown in the population cohorts is approximately 3:1 in the literature.[9,26] Recent studies have reported that, compared to children born at full term, significantly poorer

292 cognitive development[27] and school achievement (grammar and numeracy)[9] is found mainly
293 in those born at 37 weeks but not at 38 weeks of gestation. Whether there is a similar
294 difference in handwriting between children born 37 and 38 weeks of gestation requires
295 further investigation with larger sample.

296 Our results demonstrated an independent contribution of some demographic factors to
297 poor handwriting in grade two, including being younger, being male, and having mothers
298 with below collage/university education. The later-born effect on school performance was
299 consistently found in other studies, which revealed the associations between older age at the
300 entrance of elementary school and lower risk of poor handwriting[28] and higher academic
301 achievements in the first grade.[29] In addition, consistent with Feder et al's findings on English
302 legibility,[17] we also found that boys had a greater risk of having difficulties in Chinese
303 handwriting legibility than did girls. Furthermore, there was a significant association between
304 maternal education levels and the risk of poor performance in the accuracy dimension. These
305 results suggest that these demographic risk factors are important considerations in
306 investigating the handwriting performance of students in the lower elementary school grades.

307 There were a few limitations in the present study, such as a convenience sample and
308 subjective ratings of class teachers on the children's handwriting performance. A larger
309 sample size and direct handwriting assessment would be needed to confirm our findings. In

addition, future studies examining the handwriting performance of late-preterm children using different languages are also necessary.

Conclusions

This preliminary investigation indicated that children born late preterm may be at a greater risk of poor Chinese handwriting than their full-term born peers using a validated, teacher-reported handwriting questionnaire. The main handwriting problem for these children is to construct appropriate spatial relationships among components and characters. However, early-term and full-term born children have comparable risks of poor performance in all handwriting dimensions. The underlying components affecting poorer character and components construction in children born late prematurely and the proper intervention for this handwriting problem need further investigation.

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Authors' contributions

Dr. YSH designed the study, supervised data collection, interpreted the data, and drafted the manuscript. Dr. CCC contributed to data collection and data interpretation. Miss HNS performed data collection and statistical analysis. Dr. WHT contributed to the study design and data interpretation, grant application, and made critical revisions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The dataset used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the 1964 Helsinki declaration. This project was approved by the Institutional Review Board of Chi Mei Medical Center (No. 10310-006). Written informed consent was obtained from all parents and class teachers before data collection was initiated.

Consent for publication

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Table 1 Demographic data of the children and their mothers in three gestational age groups

	Late preterm (n = 54)	Early term (n = 56)	Full term (n = 75)	p
Child				
Age (month)	97.1 (3.5)	97.6 (4.2)	98.1 (4.2)	.395
boy, n (%)	31 (57.4)	21 (37.5)	32 (42.7)	.092
GA (week)	35.7 (0.8)	38.1 (0.5)	39.7 (0.7)	< .001
Birthweight (gram)	2522 (568)	3144 (425)	3182 (362)	< .001
Right handedness, n (%)	49 (90.7)	53 (94.6)	68 (90.7)	.092
Mother				
Age (year)	39.4 (3.8)	38.2 (4.3)	38.0 (4.3)	.141
Education (<college), n (%)	14 (25.9)	30 (52.7)	32 (42.7)	.016

Data are shown by mean (SD) or n (%); Late preterm: 34^{+0}-36^{+6} weeks gestation; Early term: 37^{+0}-38^{+6} weeks gestation; Full term: 39^{+0}-41^{+6} weeks gestation; GA = gestational age.

Table 2 The number and percentage of children with poor performance[a] in the CHEF

	n (%)		
	Late preterm (*n* = 54)	Early term (*n* = 56)	Full term (*n* = 75)
CHEF-full form	10 (18.5)	3 (5.4)	4 (5.3)
CHEF-dimension			
Construction	14 (25.9)	2 (3.6)	5 (6.7)
Accuracy	8 (14.8)	2 (3.6)	6 (8.0)
Speed	9 (16.7)	2 (3.6)	8 (10.7)
Pencil grasp	6 (11.1)	6 (10.7)	4 (5.3)
Directionality	7 (13.0)	3 (5.4)	8 (10.7)

CHEF = Chinese Handwriting Evaluation Form. [a] defined as a score at or below the 15th percentile of the norm; Late preterm: 34^{+0}-36^{+6} weeks gestation; Early term: 37^{+0}-38^{+6} weeks gestation; Full term: 39^{+0}-41^{+6} weeks gestation.

Table 3 Risk factors for poor handwriting in second graders (n = 185) using multivariate logistic regression analysis

Predictor	CHEF								
	Full form			Construction			Accuracy		
	aOR	(95% CI)	*p*	aOR	(95% CI)	*p*	aOR	(95% CI)	*p*
Gestational age									
Late preterm	3.93*	(1.08-14.32)	.038	4.77**	(1.48-15.37)	.009	2.21	(0.64-7.64)	.209
Early term	0.49	(0.08-3.18)	.453	0.47	(0.08-2.73)	.402	0.25	(0.04-1.55)	.136
Sex (boy)	5.56**	(1.53-20.19)	.009	7.03**	(2.05-24.05)	.002	4.78*	(1.35-16.97)	.015
Age (month)	0.81*	(0.69-0.96)	.013	0.90	(0.78-1.02)	.117	0.81*	(0.68-0.96)	.013
Maternal education (<college)	2.76	(0.84-9.12)	.095	2.11	(0.71-6.23)	.177	6.94**	(1.94-24.76)	.003

CHEF = Chinese Handwriting Evaluation Form; aOR = adjusted odds ratio; CI = confidence interval; Late preterm: 34^{+0}-36^{+6} weeks gestation; Early term: 37^{+0}-38^{+6} weeks gestation; *$p < .05$; **$p < .01$.

Table 3 (continued)

Predictor	CHEF								
	Speed			Pencil grasp			Directionality		
	aOR	(95% CI)	*p*	aOR	(95% CI)	*p*	aOR	(95% CI)	*p*
Gestational age									
Late preterm	1.43	(0.49-4.16)	.511	1.88	(0.49-7.21)	.358	1.19	(0.38-3.71)	.768
Early term	0.14	(0.02-1.20)	.073	1.90	(0.48-7.54)	.362	0.35	(0.08-1.54)	.165
Sex (boy)	2.91	(0.97-8.74)	.057	1.93	(0.64-5.59)	.246	2.26	(0.77-6.62)	.136
Age (month)	0.88	(0.77-1.01)	.076	0.96	(0.84-1.11)	.595	0.80**	(0.69-0.93)	.004
Maternal education (<college)	1.32	(0.46-3.86)	.607	0.74	(0.23-2.36)	.607	2.26	(0.87-7.51)	.087

CHEF = Chinese Handwriting Evaluation Form; aOR = adjusted odds ratio; CI = confidence interval; Late preterm: 34^{+0}-36^{+6} weeks gestation; Early term: 37^{+0}-38^{+6} weeks gestation; *$p < .05$; **$p < .01$.