Homogeneity and Heterogeneity in Early Childhood Development in Megacities: A Retrospective Cohort Study Postprint

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Abstract

Background Globally, children still face challenges of early developmental delay. The characteristics and variations of early childhood development (ECD) in economically developed regions remain unclear. Conducting ECD-related analyses based on existing child health management system databases can provide child health care professionals with more rapid and convenient directions for precise ECD monitoring. Objective This study aims to evaluate and compare ECD characteristics and their influencing factors in megacities within economically developed regions of China. Methods This was a retrospective cohort study that selected 13,436 children aged 0-3 years registered in the child health management systems of Shanghai and Shenzhen from 2017-2020 as research subjects. Child health care professionals assessed children' s basic demographic information, birth conditions, and early developmental characteristic data. Comprehensive early childhood development indicators included physical development, gross motor development, and composite developmental indicators of cognition/language/social-emotion/fine motor skills. Statistical analysis methods including descriptive analysis, univariate tests, and multivariate tests were employed to analyze ECD characteristics in Shanghai and Shenzhen and to compare the consistency and differences in ECD between the two regions. Results Among the 13,436 children aged 0-3 years, 10,890 (81.1%) were from Shanghai and 2,546 (18.9%) were from Shenzhen. Regarding physical development, children in Shenzhen had higher height and weight development scores and a higher proportion of abnormal anterior fontanelle closure time than those in Shanghai ($P<0.05$). For other dimensions of ECD, only the Shanghai regional database provided coverage; results showed that Shanghai children' s gross motor and composite cognition/language/social-emotion/fine motor development levels were both below expected age-adjusted ability levels. Multiple linear and multivariate Logistic regression analysis results indicated that summer or winter birth, birth height, birth weight, and preterm birth were common influencing factors for height development in children from both regions (P<0.05); among these, multiple births had the greatest impact on Shanghai children’ s height development (β=-0.067), while preterm birth had the greatest impact on Shenzhen children’ s height development (β=0.094). Winter birth, birth height, and preterm birth were common influencing factors for weight development in children from both regions (P<0.05); among these, multiple births had the greatest impact on Shanghai children’ s weight development (β=-0.070), while preterm birth had the greatest impact on Shenzhen children’ s weight development (β=0.066). Paternal occupation, birth season, birth weight, and gravidity were influencing factors for anterior fontanelle closure time in Shanghai children (P<0.05); among these, summer birth had the greatest impact (B=2.104). Child foreign nationality, unknown paternal occupation, summer or autumn birth, birth height, gestational weeks, and preterm birth were influencing factors for early gross motor development in Shanghai children (P<0.05); among these, preterm birth had the greatest impact (β=0.291). Child migrant status or foreign nationality, mother engaged in professional/technical work, maternal age, birth height, birth weight, gestational weeks, gravidity, cesarean section, preterm birth, and multiple births were influencing factors for early composite cognition/language/social-emotion/fine motor development in Shanghai children (P<0.05); among these, preterm birth had the greatest impact (β=0.310). Conclusion ECD levels in megacities represented by Shanghai and Shenzhen exhibit certain differences; although influencing mechanisms differ, there are certain commonalities among influencing factors. Child health care professionals can strengthen monitoring, intervention, and follow-up for children based on parental occupation, household registration type, maternal age, gestational weeks, preterm birth status, etc. Implementing early intervention during pregnancy and immediately after birth may reduce potential adverse effects of risk factors.

Full Text

Consistencies and Differences in Early Childhood Development in Megacities: A Retrospective Cohort Study

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Abstract

Background Globally, children continue to face challenges of delayed early development. The characteristics and disparities of early childhood development (ECD) in economically developed regions remain unclear. Analyzing existing child health management system databases can provide pediatric healthcare professionals with more rapid and precise directions for ECD monitoring and supervision. **Objectives** This study aimed to evaluate and compare ECD characteristics and their influencing factors in economically developed megacities in

China.

Methods This retrospective cohort study included 13,436 children aged 0–3 years registered in the Child Health Management Systems of Shanghai and Shenzhen from 2017-2020. Child healthcare physicians assessed children' s basic demographic information, birth conditions, and early developmental characteristics. Comprehensive ECD indicators included physical development, gross motor development, and integrated cognitive/language/social-emotional/fine motor development. Descriptive analysis, univariate tests, and multivariate tests were used to analyze ECD characteristics in Shanghai and Shenzhen and compare consistencies and differences between the two regions.

Results Among the 13,436 children aged 0–3 years, 10,890 (81.1%) were from Shanghai and 2,546 (18.9%) were from Shenzhen. Regarding physical development, Shenzhen children had higher height and weight development scores and higher rates of abnormal anterior fontanelle closure timing than Shanghai children ($P<0.05$). For other ECD dimensions, only the Shanghai database provided coverage. Results showed that Shanghai children' s gross motor development and integrated cognitive/language/social-emotional/fine motor development levels were below expected age-adjusted capacity levels. Multivariate linear and logistic regression analyses identified common influencing factors for height development in both cities: summer or winter birth, birth height, birth weight, and premature delivery ($P<0.05$). Multiple births had the greatest impact on Shanghai children' s height development (β=-0.067), while premature delivery had the greatest impact on Shenzhen children' s height development (β=0.094). Winter birth, birth height, and premature delivery were common influencing factors for weight development in both regions ($P<0.05$); multiple births most affected Shanghai children' s weight development (β=-0.070), while premature delivery most affected Shenzhen children' s weight development (β=0.066). Paternal occupation, birth season, birth weight, and pregnancy number influenced anterior fontanelle closure time in Shanghai children ($P<0.05$), with summer birth having the largest effect (B=2.104). Child foreign nationality, unknown paternal occupation, summer or autumn birth, birth height, gestational weeks, and premature delivery influenced early gross motor development in Shanghai children ($P<0.05$), with premature delivery having the largest effect (β=0.291). Child migrant or foreign status, maternal professional technical work, maternal age, birth height, birth weight, gestational weeks, pregnancy number, cesarean delivery, premature delivery, and multiple births influenced integrated cognitive/language/social-emotional/fine motor development in Shanghai children ($P<0.05$), with premature delivery having the largest effect (β=0.310).

Conclusion ECD levels in megacities such as Shanghai and Shenzhen demonstrate notable variations; while underlying mechanisms differ, influencing factors share certain commonalities. Child healthcare professionals can enhance monitoring, intervention, and follow-up for children based on parental occupations, household registration type, maternal age, gestational weeks, and premature

delivery status. Implementing early interventions during pregnancy and shortly after birth may reduce potential adverse effects of risk factors.

Keywords Early childhood development; Economically developed regions; Megacity; Child; Cohort study; Retrospective study; Root cause analysis

1 Introduction

Early childhood development (ECD) encompasses children' s comprehensive development in physical, social-emotional, cognitive, language, and motor domains from conception to age 8 [1]. Research demonstrates that ECD is closely associated with lifelong health, achievement, and overall social productivity, ultimately forming an intergenerational cycle of national health and social wellbeing [2]. ECD represents a major global public health concern [3]. Even in developed countries, children face risks of developmental delay [4], while in low- and middle-income countries, approximately 250 million children under age 5 (43%) fail to reach their developmental potential [5].

In China, although significant progress has been made since 2000 in reducing child malnutrition and developmental delay risks [6-7], challenges persist, including growth retardation and wasting, overweight and obesity [8], cognitive developmental delay [9], and motor developmental delay [10].

Identifying risk factors is critical for addressing poor ECD outcomes [2, 11]. Previous studies have extensively explored factors influencing ECD [12]; however, most current research focuses on single dimensions of ECD [13], particularly cognitive and motor development, lacking exploration of comprehensive ECD dimensions. Moreover, prior studies predominantly focus on vulnerable regions [14-15], while economically developed areas that represent more advanced ECD management levels lack investigation of their consistency and disparity characteristics. Evidence suggests that urbanization may negatively impact ECD, with children in economically developed megacities facing more complex environments—such as poorer natural environments and more complex social and living conditions [16]—creating uncertain influences on ECD. Therefore, in-depth exploration of early developmental characteristics among megacity children is important for promoting healthy early development in such regions.

This study analyzed and compared comprehensive ECD levels and potential influencing factors among children aged 0–3 years in Shanghai and Shenzhen, aiming to provide new evidence for ECD promotion in economically developed areas of China.

1.1 Study Participants

Data were obtained from records in the Shanghai and Shenzhen Child Health Management Systems from 2017–2020. Shanghai data came from two administrative districts covering urban, suburban, and urban-suburban combined areas;

Shenzhen data came from a specialized maternal and child healthcare hospital serving the entire city, providing balanced and comparable data across regions. Using a 95% confidence level, 0.01 margin of error, and 16.0% ECD delay rate in China' s most developed regions [6], the minimum required sample size was calculated as 5,164. Ultimately, this study used convenience sampling to include 13,436 children aged 0–3 years, with 10,890 from Shanghai and 2,546 from Shenzhen.

Inclusion criteria: (1) continuous, complete records in the system; (2) no major diseases or disabilities. Exclusion criteria: incomplete system records. This study was approved by the Ethics Committee of the School of Public Health, Shanghai Jiao Tong University School of Medicine (approval number: SJUPN-202109), with informed consent waived.

1.2 Data Collection

As China' s ECD database has not yet achieved national standardization, this study extracted the following indicators monitored in Shanghai and Shenzhen for comparison: demographic information, birth status indicators, and comprehensive ECD indicators. Demographic information included child gender, household registration type, parental occupations, and parental ages. Birth status indicators included birth season, birth height, birth weight, gestational weeks, pregnancy number, parity, delivery mode, premature delivery, and multiple birth status. Comprehensive ECD indicators included physical development, gross motor development, and integrated cognitive/language/social-emotional/fine motor development.

1.3 ECD Assessment

All comprehensive ECD assessment results included in this study were obtained through professional evaluation by child healthcare physicians; physicians conducting ECD assessments in Shanghai and Shenzhen were all qualified doctors with systematic education and training. First, early childhood physical development indicators included height, weight, and anterior fontanelle closure time. Height and weight for children under 6 in Shanghai and Shenzhen were evaluated using the "Shanghai-2015" and "WHO-2006" standards, respectively—both mature standards applicable for local ECD level evaluation with support from years of practice and research [17-18]. Since children have different ages in months, comparing only their latest or average values would be unreasonable. Therefore, this study used percentile consistency and weighted methods to eliminate comparison difficulties caused by age differences.

1.3.1 Height and Weight In the Shanghai and Shenzhen child health management systems, each monitoring value automatically corresponds to a percentile interval including <P3, P3-P10, P10-P20, P20-P50, P50-P80, P80-P97, >P97. Based on these percentiles, each monitoring value was assigned a score: height or weight below P3 scored -1; P3-P10, P10-P20, P20-P50, P50-P80, and

P80-P97 scored 0–4, respectively; above P97 scored 5. A child's total score for N height or weight monitoring instances was (X1+X2+···+Xn). The highest possible score within the normal range (P3-P97) should be 4N. Therefore, a child's height or weight development level was calculated as (X1+X2+···+Xn)/4N, interpreted as the development level relative to the maximum possible score. This scoring and calculation process enables comparison of height and weight across children of different ages, with higher scores indicating taller height or heavier weight.

1.3.2 Anterior Fontanelle Closure Time Anterior fontanelle development level was assessed based on closure time. Evidence from nine Chinese cities indicates normal closure time ranges from 6.6 to 22.4 months [19]. Closure within this range was considered normal development. If fontanelle closure was not observed in children under 22.4 months, this was assessed as a normal non-closure stage. Closure before 6.6 months was considered premature; closure after 22.4 months was considered delayed.

1.3.3 Early Gross Motor Development and Integrated Cognitive/Language/Social-Emotional/Fine Motor Development Both domains were assessed by physicians using the Denver Development Screening Test II (DDST-II) [20]. This scale's sensitivity, specificity, false positive rate, false negative rate, correct diagnosis rate, and concordance rate have been validated internationally and domestically [21]. Child healthcare physicians recorded children's ability levels and corresponding age in months ("measurement age") during each assessment, allowing calculation of the difference between measurement age and actual age as the ability development score. Gross motor and integrated cognitive/language/social-emotional/fine motor development levels were calculated as the average of each assessment score. Negative scores indicated developmental delay; positive scores indicated advanced development, with higher scores indicating better developmental levels.

1.4 Statistical Methods

IBM SPSS Statistics (v.22.0) was used for statistical analysis. Descriptive analysis clarified children's basic characteristics. Normally distributed measurement data were expressed as ($\bar{x}\pm s$), with independent samples t-tests for between-group comparisons. Count data were expressed as frequencies and percentages, with ^{2} tests for between-group comparisons. Second, based on variable types, t-tests, one-way ANOVA, Pearson correlation analysis, and ^{2} tests were used for univariate analysis to explore associations between single factors and ECD. Finally, factors with statistical significance in univariate analysis were included in multiple linear regression or logistic regression models to analyze ECD influencing factors. Variance inflation factor (VIF) was used for multicollinearity testing; VIF values <5 indicated no significant multicollinearity. P<0.05 was considered statistically significant.

2 Results

2.1 Comparison of Basic Characteristics Between Shanghai and Shenzhen Children

Among the 13,436 children aged 0-3 years, 10,890 (81.1%) were from Shanghai and 2,546 (18.9%) were from Shenzhen. No statistically significant differences were found between Shanghai and Shenzhen children in gender or birth height (P>0.05). Significant differences were observed in household registration type, maternal occupation, maternal age, birth season, birth weight, gestational weeks, pregnancy number, delivery mode, and premature delivery status (P<0.05) .

2.2 Comparison of ECD Characteristics Between Shanghai and Shenzhen Children

Regarding physical development, significant differences were found between Shanghai and Shenzhen children in height development scores, weight development scores, and anterior fontanelle closure time proportions (P<0.05). Specifically, Shenzhen children had higher height and weight development scores and higher rates of abnormal anterior fontanelle closure timing than Shanghai children (P<0.05). For other ECD dimensions, only the Shanghai database provided coverage. Results showed Shanghai children' s gross motor development (-0.2$±0.3)*andintegratedcognitive/language/social − emotional/finemotordevelopment*(−0.2±$0.5) were below expected age-adjusted capacity levels (0.0) .

2.3 Influencing Factors of ECD

2.3.1 Influencing Factors of Early Childhood Height Development Univariate analysis showed Shanghai children' s height development scores correlated with gender, household registration type, paternal occupation, maternal occupation, birth season, birth height, birth weight, gestational weeks, pregnancy number, parity, delivery mode, premature delivery status, and multiple births (P<0.05) . These factors were included in multivariate analysis, with VIF values <5 (1.012-3.530). Multiple linear regression showed child gender, migrant status, summer or winter birth, birth height, birth weight, gestational weeks, pregnancy number, parity, multiple births, and premature delivery were influencing factors for Shanghai children' s height development (P<0.05), with multiple births having the largest effect (β=-0.067) .

Univariate analysis showed Shenzhen children' s height development scores correlated with maternal occupation, birth season, birth height, birth weight, gestational weeks, pregnancy number, and premature delivery status (P<0.05) . Multivariate analysis showed VIF values <5 (1.005-4.402). Multiple linear regression showed summer or winter birth, birth height, birth weight, and premature delivery were influencing factors for Shenzhen children's height development (P<0.05), with premature delivery having the largest effect (β=0.094) .

2.3.2 Influencing Factors of Early Childhood Weight Development Univariate analysis showed Shanghai children' s weight development scores correlated with household registration type, paternal occupation, maternal occupation, birth season, birth height, gestational weeks, pregnancy number, parity, delivery mode, premature delivery status, and multiple births ($P<0.05$) . Multivariate analysis showed VIF values <5 (1.004–3.520). Multiple linear regression showed winter birth, birth height, gestational weeks, parity, premature delivery status, and multiple births were influencing factors for Shanghai children' s weight development ($P<0.05$), with multiple births having the largest effect (β=-0.070) .

Univariate analysis showed Shenzhen children' s weight development scores correlated with maternal occupation, birth season, birth height, birth weight, gestational weeks, pregnancy number, and premature delivery status ($P<0.05$) . Multivariate analysis showed VIF values <5 (1.005–4.402). Multiple linear regression showed summer or winter birth, birth height, birth weight, and premature delivery were influencing factors for Shenzhen children's weight development ($P<0.05$), with premature delivery having the largest effect (β=0.066) .

2.3.3 Influencing Factors of Anterior Fontanelle Closure Time Univariate analysis showed Shanghai children' s anterior fontanelle closure time correlated with household registration type, paternal occupation, maternal occupation, maternal age, birth season, birth weight, pregnancy number, and delivery mode ($P<0.05$) . Multivariate analysis showed VIF values <5 (1.060–2.784). Multivariate logistic regression showed paternal occupation in business/services or production/transportation operations, summer/autumn/winter birth, birth weight, and pregnancy number were influencing factors for Shanghai children' s anterior fontanelle closure time ($P<0.05$), with summer birth having the largest effect (B=2.104) .

Univariate analysis showed no correlation between Shenzhen children' s anterior fontanelle closure time and any factors ($P>0.05$) .

2.3.4 Influencing Factors of Early Gross Motor Development Univariate analysis showed Shanghai children' s early gross motor development scores correlated with household registration type, paternal occupation, birth season, birth height, gestational weeks, and premature delivery ($P<0.05$) . Multivariate analysis showed VIF values <5 (1.095–3.524). Multiple linear regression showed child foreign nationality, unknown paternal occupation, summer or autumn birth, birth height, gestational weeks, and premature delivery were influencing factors for Shanghai children' s early gross motor development ($P<0.05$), with premature delivery having the largest effect (β=0.291) .

2.3.5 Influencing Factors of Integrated Cognitive/Language/Social-Emotional/Fine Motor Development Univariate analysis showed Shanghai children' s integrated cognitive/language/social-emotional/fine motor development scores correlated with household registration type, paternal occupation, maternal occupation, maternal age, birth season, birth height, birth weight, gestational weeks, pregnancy number, parity, premature delivery status, and multiple births ($P<0.05$) . Multivariate analysis showed VIF values <5 (1.144–3.327). Multiple linear regression showed child migrant or foreign status, maternal professional technical work, maternal age, birth height, birth weight, gestational weeks, pregnancy number, cesarean delivery, premature delivery, and multiple births were influencing factors for Shanghai children' s integrated development ($P<0.05$), with premature delivery having the largest effect (β=0.310) .

3 Discussion

Consistent with previous research conclusions, maternal age, birth weight, and premature delivery status are widely recognized as key influencing factors of ECD [12,22-24]. However, unlike other studies, this study was based on existing child health management system databases rather than surveys of socioeconomic and family environmental factors. This approach will help healthcare professionals in other regions more quickly and conveniently identify high-risk children with early developmental delays based on their management databases.

This study focused on early childhood development in megacities, describing and comparing the current status of ECD and its influencing factors in typically representative megacities, providing new evidence for ECD promotion in economically developed areas of China. The study found that Shenzhen children had higher height and weight development scores and higher rates of abnormal anterior fontanelle closure timing than Shanghai children. Shanghai children' s gross motor development and integrated cognitive/language/social-emotional/fine motor development lagged behind age-adjusted standard levels. ECD was primarily influenced by children' s and parents' demographic characteristics, birth characteristics, and maternal characteristics.

This study found that children whose mothers engaged in professional technical work and those whose fathers engaged in business/services or production/transportation operations were more likely to experience delays in integrated cognitive/language/social-emotional/fine motor development and abnormal anterior fontanelle closure. Previous studies have shown that parental occupation is an important predictor of ECD [25], likely related to family socioeconomic status and parent-child interaction time. Parents in high-intelligence occupations have stronger abilities to absorb new knowledge and parenting information and may pay more attention to children' s overall development [26]. Parents in lower-social-status, lower-wage, less stable jobs typically have reduced time for child companionship [27], negatively impacting children' s language, mathematics, and social development [28]. Therefore, it is essential to recognize that parental investment in child-rearing, particularly ensuring adequate parent-child interaction time, positively affects child development [29]. Child healthcare professionals should conduct precise, differentiated interventions based on parental occupation and family background. While professionally employed parents may have higher education levels and knowledge acquisition abilities, they may also face challenges of long or irregular working hours reducing parent-child interaction time. Therefore, child healthcare professionals could consider community parenting activities and training, supervision, home visits, or communication feedback to ensure such parents invest more time interacting with their children [30]. For parents engaged in business/services or production/transportation operations, high-quality electronic media content may be beneficial [31]. However, it is crucial to emphasize that frequent electronic media exposure without parent-child interaction [34] completely offsets electronic media advantages and significantly negatively impacts ECD, with this negative effect being more pronounced in low socioeconomic status families [34]. Therefore, child healthcare professionals should provide more professional guidance on parent-child interaction and media application when guiding such families to use electronic media for ECD promotion [30].

Notably, the above findings regarding paternal occupation' s impact on ECD are not highly consistent across countries and regions, with contradictory evidence existing. For example, a Chinese survey across 12 cities found no significant effect of paternal occupation type on early childhood social-emotional development [35]; a Philippine study showed paternal occupation type had no significant effect on early cognitive development [36]; and a Canadian cohort study found paternal occupation type was not a predictor of early social-emotional development [37]. Therefore, considering the insufficient analysis and comparison due to missing paternal occupation characteristics in Shenzhen, combined with the current widespread neglect of paternal occupation in most existing research [38], more evidence and discussion from additional regions are needed regarding paternal occupation' s impact on ECD.

In Shenzhen, where height and weight development scores were higher, the proportion of abnormal anterior fontanelle closure timing was also higher, indirectly indicating that early fontanelle development may be associated with physical development. Although previous research on the association between anterior fontanelle closure time and early physical development is limited and lacks consistent conclusions, it is noteworthy that a Chinese retrospective cohort study of 140,000 preschool children found that children with earlier fontanelle closure typically demonstrated faster early height development [39], and another Chinese cross-sectional study of nine cities also suggested that children with earlier fontanelle closure had significantly greater height and weight than those with later closure [40]. These findings are consistent with our results: Shenzhen children had earlier anterior fontanelle closure timing and correspondingly higher height development scores. This suggests that child healthcare professionals can implement more precise early height development interventions and management by monitoring fontanelle closure timing. For example, nutritional enhancement interventions could be implemented for children with earlier fontanelle closure, while dietary and exercise interventions could be provided for children with later closure to reduce potential height development delays [39]. Additionally, this study found that Shanghai children' s anterior fontanelle closure time was significantly associated with birth season, birth weight, pregnancy number, and paternal occupation, but these findings were not validated in Shenzhen, and existing research lacks exploration of these factors. Therefore, more evidence from different countries and regions is needed to further validate the impact of these factors on fontanelle closure timing.

Notably, maternal characteristics are a key factor requiring special attention in ECD, as their adverse effects may be reduced or eliminated through more effective education and interventions. First, older maternal age is a protective factor for comprehensive child development, likely because these mothers have received more years of parenting education and experience, promoting healthier prenatal environments and postnatal environments that stimulate early development, enabling better child development outcomes [41]. Second, higher pregnancy numbers negatively impact ECD, possibly related to maternal nutritional status [42]. Therefore, women with multiple pregnancies should be prioritized targets for ECD promotion interventions [43]. Third, parity effects are opposite to pregnancy number effects, with multiparous women more likely to achieve early breastfeeding initiation. This finding suggests that breastfeeding benefits immunity, cognition, and motor development [44], and child healthcare professionals should conduct more effective breastfeeding education during prenatal care and child-rearing to help mothers provide high-quality infant feeding at appropriate times.

In addition to these modifiable factors, this study also identified some difficult-to-intervene high-risk factors. (1) Although domestic and international studies, including ours, have found that premature delivery significantly negatively impacts all dimensions of early childhood development [45-46], few interventions can prevent preterm birth. Therefore, to minimize adverse effects of prematurity, child healthcare professionals should intervene as early as possible after preterm infants' birth—intervention within hours or days carries significant meaning [47] and may reduce early emotional and behavioral problems while improving motor and/or cognitive abilities in preterm infants [48]. (2) Birth weight, birth height, and delivery mode also affect ECD levels. Expanding the time frame for prenatal and postpartum 42-day visits and integrating more precise interventions may provide additional benefits. For example, nutritional interventions and dietary-exercise guidance for high-risk pregnant women can help prevent low birth weight and macrosomia, effectively reducing cesarean delivery rates and improving neonatal quality [49]. (3) Regarding birth season associated with poorer ECD outcomes, child healthcare professionals should intervene early after birth to increase parenting guidance and follow-up for children born in different seasons. For example, infants born in winter have more opportunities for environmental stimulation and sustained outdoor activities at 6 months, contributing to higher cognitive and motor development [50]; conversely, infants born in summer should receive more interventions to mitigate adverse seasonal effects.

4 Conclusion

In summary, ECD levels in Chinese megacities represented by Shanghai and Shenzhen demonstrate certain differences: Shenzhen children had higher height and weight and higher rates of abnormal anterior fontanelle closure; Shanghai children' s gross motor development and integrated cognitive/language/social-emotional/fine motor development lagged behind age-adjusted capacity standards. Influencing factors of ECD in Chinese megacities share certain commonalities, primarily affected by biological factors including premature delivery, birth weight and height, delivery mode, and birth season, as well as social-environmental factors including maternal age and parental occupations. Child healthcare professionals should implement more precise interventions for more vulnerable children, high-risk occupational parents, and high-risk mothers based on different factors' mechanisms and effect sizes. Early intervention during pregnancy and shortly after birth for difficult-to-control risk factors may reduce their adverse effects.

Author Contributions: Xiang Liu conceptualized the study, designed the research protocol, proposed the comparative research proposition on ECD in megacities, oversaw implementation, verified statistical analysis results, and drafted the manuscript. Hong Chen conducted data cleaning, descriptive, univariate, and multivariate statistical analyses, and revised the manuscript. Rui Cui, Zhichao Guo, Panpan Li, Zilong Cao, and Yiqing Ji collected data, conducted data verification and cleaning, and revised the manuscript. Wenya Yu revised the final version and takes responsibility for the manuscript.

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5 Limitations

This study has several limitations. (1) As data were derived from existing child health management system databases, some factors with significant ECD impact were not included. (2) Currently, no national standard exists for child health management systems, so this study only achieved comparison of early physical development characteristics between Shanghai and Shenzhen; comparisons of other dimensions could not be completed. (3) Quality varies significantly across regional child health management systems, with problems including missing important data (e.g., paternal occupation and age, maternal parity in Shenzhen) and unreasonable data entry settings (e.g., "unknown" maternal occupation type), reducing accuracy of some results and comparability across regions. (4) ECD assessment data recorded in current management systems have not distinguished cognitive, language, social-emotional, and fine motor development, limiting accurate assessment to some extent. (5) The Shanghai:Shenzhen sample size ratio is approximately 4:1, with Shenzhen' s sample clearly insufficient; although research indicates this ratio meets minimum requirements for test power

[51] and the overall sample size is large, it remains necessary to substantially expand Shenzhen' s sample size in future research to effectively improve test power. (6) This study only compared two southeastern coastal cities (Shanghai and Shenzhen), lacking comparative evidence from other megacities in central and western China (e.g., Beijing), somewhat limiting the generalizability of findings and conclusions. Future research should introduce operationally strong assessment tools for both providers and users based on current management systems and promote application in more regions to achieve multi-dimensional, regional ECD assessment and multi-center comparisons. (7) This study included only 34 foreign children in Shanghai; although findings showed these children had generally poor ECD outcomes except for physical development, the small sample size requires further validation.

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Tables

Table 1 Comparison of children' s basic characteristics in the Shanghai-Shenzhen regions

Table 2 Comparison of ECD indicators between Shanghai and Shenzhen

Table 3 Univariate analysis results of ECD in Shanghai and Shenzhen

Table 4 Multivariate analysis results of ECD in Shanghai

Table 5 Multivariate analysis results of ECD in Shenzhen

Note: Figure translations are in progress. See original paper for figures.