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# Protection or risk: individual and environmental factors associated with early childhood development in a cross-sectional study

| Journal:          | BMJ Open                           |
|-------------------|------------------------------------|
| Manuscript ID:    | bmjopen-2022-065936                |
| Article Type:     | Original research                  |
| Date Submitted by the Author: | 23-Jun-2022 |
| Complete List of Authors: | Schild, Clara; Leipzig University, LIFE Leipzig Research Center for Civilization Diseases  
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| Keywords:         | PAEDIATRICS, Developmental neurology & neurodisability <  
PAEDIATRICS, Community child health < PAEDIATRICS, SOCIAL MEDICINE, PUBLIC HEALTH |
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Protection or risk: individual and environmental factors associated with early childhood development in a cross-sectional study

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Word count: 3880

Keywords: child development, socioeconomic status, gestational age, cognitive development, language development
ABSTRACT

Objectives To explore environmental and individual factors that are associated with children's neurodevelopment and to investigate whether the strength of these associations differs according to the age of the children.

Design Cross-sectional study

Setting This study was part of the LIFE Child study, a large cohort study conducted in Leipzig, Germany.

Participants 778 children between 0.5 and 6 years of age (48.6% female, mean age = 2.67 years).

Primary and Secondary outcome measures The outcomes were cognitive development, language development, body motor skills, hand motor skills, social-emotional development, and tracing skills, measured with a standardized development test. We applied linear mixed effect models to analyze the associations between development in each domain and gestational age, socioeconomic status (SES), child sex, behavioral difficulties, siblings, sleep duration, breastfeeding duration, and overweight/obesity. We also tested for interactions between these variables and child age or sex.

Results Higher gestational age and higher SES were associated with better outcomes in almost all developmental domains. Children with older siblings had improved body and hand motor skills compared to children without older siblings. Boys had poorer scores than girls in body and hand motor skills and tracing. Children with behavioral difficulties had significantly poorer outcomes in most developmental domains. Some of the associations with SES and sex were stronger in older than in younger children. Associations between gestational age and motor development were weaker in older than in younger children. We did not find associations between child development and sleep duration, breastfeeding duration, or overweight/obesity.

Conclusion We identified factors that had a protective effect and factors that posed a risk to the development of children under 6 years of age. The effect of SES and sex increased with age. The effect of gestational age decreased as children got older.
INTRODUCTION

Early child development is the basis for later academic, professional, and personal success.[1,2] As a complex and variable process, it is influenced by numerous individual (psychosocial or biological) and environmental factors. These factors might be protective or pose a risk to child development. Knowledge of both unchangeable and variable factors helps clinicians, teachers, and policy makers to target children who are at risk and to correctly evaluate their developmental status.

Low gestational age at birth is a major developmental risk for children. Children born prematurely (<37th week of gestation) are at increased risk for developmental delays in cognition, language, motor skills, and social-emotional development.[3–5] In general, the earlier children are born, the greater their developmental disadvantages.[6] This phenomenon is stronger in boys than in girls.[7–9] Some studies have shown that even children born mature but before 39 weeks of gestation show a slightly increased risk of developmental deficits.[4,6] While some longitudinal studies show that developmental deficits decrease or disappear as children grow older (at least in children born after the 34th week of gestation),[4,10] other studies show that differences between preterm and term-born infants persist even at school age.[11,12]

The relationship between a family's socioeconomic status (SES) and their children's development has been examined for decades.[13] Children from poorer social backgrounds were found to show developmental delays[14,15] from as early as 7 months of age.[16] Several studies have shown that these disadvantages increase over childhood.[16,17] In line with this assumption, several studies showed an increased risk for achievement gaps in school between children from low- and high-SES families.[13,16,18] Nevertheless, the trajectory of the association between SES and development or academic success as children grow older is a recurring subject of debate.[18,19]

In some studies, it was noticed that girls performed better in development tests than boys.[14,20–22] In Krogh and Væver's study, girls already achieved better results in some developmental domains at 7 months of age.[23] Behavior during testing did not differ between boys and girls, so that is probably not the reason for the differing results.[23] Many studies observed sex differences regarding language development,[20,24,25] however, differences in
the cognitive domain in favor of girls have also been frequently observed.[14,21,23] Regarding motor skills, the results of previous studies have been ambiguous.[21–23,26]

There is already a large body of research on the relationship between poor language development and behavioral difficulties, such as internalizing or externalizing problems, inattention, or hyperactivity.[27–29] The data on other developmental domains is much more limited, although negative associations were also found in the motor and cognitive domains.[30,31]

As children usually spend a lot of time with their siblings and as interactions with older or younger children might affect their own development, several scientists assumed an association between the presence of siblings and children's development. However, previous study results showed a mixed picture. In some studies, the presence of siblings was negatively associated with development in several domains.[22,26] Other studies observed positive associations, especially regarding (fine) motor skills.[32,33]

Poor sleep quantity and quality might also be associated with developmental delays. In experimental studies in which children were exposed to sleep restriction, weaker performance was observed in demanding cognitive tasks, reaction time measures, and working memory.[34] Studies examining the effects of different sleep patterns on children's cognitive, language, and academic performance revealed mixed results.[34,35] In some studies, children who slept less or later showed weaker performance.[36–38] However, other studies found no significant association between sleep duration[39,40] or sleep disruptions[40,41] and development.

Breastfeeding has many positive effects on infant health,[42] but there is controversy about the relationship between breastfeeding and cognitive development. While many studies showed a positive effect of breastfeeding, there is also some evidence that this effect is largely caused by confounders.[43] Two studies examined sibling cohorts to exclude as many confounders as possible. One found no significant developmental differences between the breastfed children and their non-breastfed siblings.[44] In the other study, the developmental advantages of breastfed infants remained significant even among discordant sibling pairs.[45]

As overweight and obesity have a high prevalence among children and adolescents in Germany (15.4 % of 3- to 17-year-olds),[46] it is important to investigate possible effects on health and development. However, so far there is little evidence for a direct effect of being overweight/obese on cognitive development or academic performance. In one study, boys with
overweight had weaker math and literacy skills compared to normal-weight peers, while no significant differences were found in girls.[47] Several studies found no significant effect of overweight/obesity on cognition or academic achievement at all.[48,49] Interestingly, a study on this topic in very young children aged 6 to 24 months found significantly lower scores among children with overweight/obesity in the cognitive and motor domains compared to normal-weight children.[50]

The aim of the present study is to investigate the associations of gestational age, SES, child sex, behavioral difficulties, siblings, sleep duration, breastfeeding, and overweight/obesity with the neurodevelopment of German children. Many of the previous studies on early childhood development examined only one of the influencing variables and its effect on a single developmental domain at a given age point. Our relatively large sample of 778 children includes children of all ages between 6 months and 6 years and consists of recently collected data (September 2016 to October 2020). This allows us to take a look at child development over the entire preschool period. We take into account multiple influencing factors and their effects on the different developmental domains of cognition, language, body and hand motor skills, and social-emotional development. Based on the results of previous studies, we expected higher gestational age, higher SES, longer average sleep duration, and longer breastfeeding duration to be positively associated with child development. We suspected poorer development for boys compared to girls, for children with older siblings, and for children showing more behavioral difficulties. We expected no differences in development if children were overweight/obese.

A specific focus was put on possible changes in the strengths of associations depending on child age. We hypothesized the association between SES or sex and development to be more pronounced in older children. In contrast, we expected the association between gestational age and development to be stronger in younger children. We further expected the association between development and gestational age to be more pronounced in boys than girls.

**METHODS**

**Participants and Design**

Data collection was conducted as part of the LIFE Child study. The LIFE Child study is a large population-based cohort study conducted at the Research Center for Civilization Diseases, Leipzig University. The study focuses on the physical and psychological development of healthy children from the prenatal phase to the age of 20.[51,52] Study participants are recruited since 2011 at public health centers, hospitals, and by word of mouth. In our analysis, we
included all children between 0 and 6 years of age who performed the development test as part of the study program and whose parents provided information on their SES and the gestational age of their children. If children participated more than once, only the last visit was taken into account. Data was collected between September 2016 and October 2020. The final sample consisted of 778 0.35 - to 5.63-year-old children (48.6 % female, mean age = 2.67 years, see Figure 1). However, due to assessment-specific missings, the sample size was smaller for some analyses (min = 259 children aged 0.88 to 5.9 years).

Measures

Development Test

In order to assess the development of the children, we applied the revised version of the Entwicklungstest 6 Monate – 6 Jahre (“Development Test for Children between 6 Months and 6 Years – Revision”, ET 6-6-R).[53] This standardized test for children between 6 months and 6 years of age assesses the developmental stage regarding cognition, language, body and hand motor skills as well as social-emotional skills. Children older than 42 months also complete a tracing subtest. Information on social-emotional development is collected through a questionnaire completed by parents. The other domains are assessed using age-specific standardized test items. The number of successfully completed items is converted into a developmental quotient (M = 10, SD = 3), based on age-specific references.[53] The ET 6-6-R is administered on an additional study day by trained study assistants. For the cognition and language scales of the ET 6-6-R, significant correlations with the children's intelligence quotient could be demonstrated.[54] For the more comprehensive validated precursor of the ET 6-6-R, significant correlations of individual scales with the corresponding Bayley Scales of Infant Development II and another specific language development test were shown.[55]

Socioeconomic status (SES)

A family’s SES was determined on the basis of a parental questionnaire originally developed for the “Studie zur Gesundheit von Kindern und Jugendlichen in Deutschland” (Study on the health of children and adolescents in Germany, KiGGS).[56] The questionnaire collects data on parental education, occupational status, and equivalent household income.[56] Information on these three parameters is combined to an SES index ranging between 3 (indicating low SES) and 21 (indicating high SES). Based on cut-off values created in a large representative German
sample, the SES index can be categorized as reflecting either low, middle, or high family SES. In a representative sample, the distribution of low-middle-high would be expected to be 20%-60%-20%.[56]

**Behavioral strengths and difficulties**

The parent version of the Strengths and Difficulties Questionnaire (SDQ) was used to assess behavioral strengths and difficulties in children aged 3 years and older. This screening questionnaire comprises five scales, namely emotional problems, hyperactivity/inattention, peer relationship problems, conduct problems, and prosocial behavior. The results of the four different problem scales (all scales but prosocial behavior) can be combined into a total difficulties score, which ranges from 0 to 40, with higher scores indicating more behavioral difficulties.[57] This score was used for further analysis.

**Overweight/Obesity**

Height and weight of all participants were measured by trained study assistants. BMI was calculated and converted to standard-deviation scores (BMI-SDS) using age- and gender-specific percentiles for German children.[58] For data analysis, BMI-SDS was categorized as either normal weight (≤ 90th percentile) or overweight/obesity (>90th percentile).[58]

**Sleep duration**

Information on sleep habits was collected using parent questionnaires. For children up to 2 years of age, the Brief Infant Sleep Questionnaire (BISQ) was used. For older children, we applied the Children’s Sleep Habits Questionnaire (CSHQ).[59,60] From both questionnaires, only the information on sleep duration was considered. The hours of sleep per day and night were summed to obtain the total sleep time.

**Breastfeeding, gestational age at birth, and siblings**

Information on breastfeeding was collected using a parent questionnaire. Parents were asked to indicate how many months the child was breastfed, regardless of whether it was exclusively breastfed or not. In another questionnaire, parents provided information on the number of older
siblings of the child. From this information, we created a binary variable that indicates whether a child has at least one older sibling or not. Information on gestational age at birth was taken from medical records. In order to obtain accurate data, the fully completed weeks of pregnancy and the additional days were added.

**Analysis**

Data analysis was performed using R. We applied linear mixed-effect models to explore associations between the influencing variables and the developmental outcomes in the different domains. The developmental quotients in the domains of cognition, language, body motor, hand motor, social-emotional development, and tracing were included as dependent variables. Gestational age, sex, SES, the presence of older siblings, overweight/obesity, sleep duration, breastfeeding duration, and total difficulties score were included as independent variables. Separate models were calculated for each independent variable. All associations were adjusted for age and sex and controlled for possible family relationships within the study sample (package lmer).

Following our hypotheses, associations between developmental outcomes and gestational age, sex, and SES were checked for interactions with child age at examination. Furthermore, associations between developmental outcomes and gestational age were checked for interaction with sex.

For all associations, the level of significance was set at $\alpha = 0.05$.

**Patient and public involvement**

Study participants or members of the public were not involved in the design of this study. At regular public events organized by the LIFE Child study, such as open days, study participants and members of the public are invited to learn about our latest research findings.

**RESULTS**

**Description of the study sample**

For each variable, sample size and distribution within the sample are shown in Error! Reference source not found.. The majority of the families (51.9%) had high SES, 46.4 % had medium SES, and 1.7 % had low SES. 50 of 767 children (6.52 %) were overweight or obese. Information on siblings was available for 494 children, of whom 269 (54.5%) had no older
siblings. The average developmental quotients of the ET 6-6-R ranged from 9.4 (SD = 2.88) to 10.61 (SD = 2.68, see Figure 2), depending on the developmental domain, and thus correspond approximately to the average for German children.[53]
Table 1 - Characteristics of the sample.

|                         | n     | Distribution        |
|-------------------------|-------|---------------------|
| **Sex**                 | 778   |                     |
| Female                  | 378   | (48.6 %)            |
| Male                    | 400   | (51.4%)             |
| **Older siblings**      | 494   |                     |
| No                      | 269   | (54.5 %)            |
| Yes                     | 225   | (45.5 %)            |
| **Overweight/Obesity**  | 767   |                     |
| No                      | 717   | (93.48 %)           |
| Yes                     | 50    | (6.52 %)            |
| **SES status**          | 778   |                     |
| high                    | 404   | (51.9 %)            |
| middle                  | 361   | (46.4 %)            |
| low                     | 13    | (1.7 %)             |

|                         | n     | Range         | Mean (SD)           |
|-------------------------|-------|---------------|---------------------|
| **Age (years)**         | 778   | 0.35 – 5.98   | 2.67 (1.78)         |
| **SES index**           | 778   | 6.9 – 21      | 15.52 (2.95)        |
| **Gestational age (weeks)** | 778   | 24.29 – 42.14 | 39.48 (2.16)        |
| **SDQ score**           | 391   | 0 – 26        | 8.52 (4.32)         |
| **Sleep time (hours/day)** | 365   | 6 – 16.6      | 12.18 (1.7)         |
| **Breastfeeding duration (months)** | 259   | 1 – 36        | 11.05 (5.4)         |
| **Developmental quotient** | 778   |               |                     |
| Cognition               |       | 1 – 17        | 10.03 (2.97)        |
| Language                |       | 1 – 15        | 10.06 (2.65)        |
| Body motor              |       | 1 – 17        | 9.4 (2.88)          |
| Hand motor              |       | 1 – 16        | 10.14 (2.76)        |
| Social-emotional        |       | 1 – 17        | 10.61 (2.68)        |
| Tracing                 | 307   | 1 – 18        | 10.21 (2.99)        |
**Associations between social and individual factors and developmental outcomes**

As expected, higher gestational age was associated with better development in the domains of cognition, language, body motor skills, hand motor skills, and social-emotional development (b ranging between .12 and .24, all p < .008, see Error! Reference source not found.). Only tracing was not significantly associated with gestational age (b = .05, p = .589).

Also in line with the hypotheses, a higher SES was significantly associated with the developmental outcomes in the domains of cognition, language, body motor skills, social-emotional development, and tracing (b ranging from .08 to .21, all p < .019) Only developmental scores in the domain of hand motor skills showed no significant association with SES (b = .06, p = .09).

As expected, boys scored lower than girls in all developmental domains. However, the differences only reached significance in the domains of body and hand motor skills (b = -.45 and -.68, p = .019 and <.001, respectively) and tracing (b = -1.5, p = <.001, see Error! Reference source not found.).

Compared to gestational age, SES, and sex, the other independent variables showed fewer significant associations with the developmental outcomes. Regarding behavioral difficulties, a higher total difficulties score was significantly associated with poorer performance in the areas of cognition, hand motor skills, social-emotional development, and tracing (b ranging between -.08 and -.13, all p < .018).

The presence of older siblings was significantly associated with better motor skills (both b = .55, both p < .029), but not with development in other domains (see Error! Reference source not found.).

The associations between developmental outcomes and sleep duration, breastfeeding duration, and overweight/obesity were not significant (see Error! Reference source not found.).
Table 2 - Associations of social and individual variables with developmental outcomes.

| N     | Cognition         | Language         | Body motor       | Hand motor       | Social-emotional | Tracing a |
|-------|-------------------|------------------|------------------|------------------|------------------|-----------|
|       | b (95% CI)        | p                | b (95% CI)       | p                | b (95% CI)       | p         |
|-------|-------------------|------------------|------------------|------------------|------------------|-----------|
| Gestational age | 778  |
|        | 0.24 (0.15 – 0.33) *** <0.001 |
|        | 0.19 (0.11 – 0.28) *** <0.001 |
|        | 0.21 (0.12 – 0.30) *** <0.001 |
|        | 0.26 (0.17 – 0.34) *** <0.001 |
|        | 0.12 (0.03 – 0.21) ** 0.008 |
|        | 0.05 (-0.12 – 0.21) 0.589 |
| SES Score | 778  |
|        | 0.12 (0.05 – 0.18)b ** 0.001 |
|        | 0.12 (0.06 – 0.18)b *** <0.001 |
|        | 0.08 (0.02 – 0.15) * 0.013 |
|        | 0.06 (-0.01 – 0.12) 0.09 |
|        | 0.08 (0.01 – 0.15) * 0.019 |
|        | 0.21 (0.11 – 0.32) *** <0.001 |
| Sex (ref = female) | 778  |
|        | -0.40 (-0.80 – 0.00) 0.050 |
|        | -0.31 (-0.65 – 0.04) 0.079 |
|        | -0.45 (-0.83 – -0.07)b * 0.019 |
|        | -0.68 (-1.05 – -0.31)b *** <0.001 |
|        | -0.26 (-0.63 – 0.10) 0.157 |
|        | -1.50 (-2.14 – -0.86) *** <0.001 |
| SDQ total-score | 391  |
|        | -0.08 (-0.15 – -0.01) * 0.018 |
|        | -0.03 (-0.09 – -0.03) 0.372 |
|        | -0.06 (-0.12 – -0.00) 0.067 |
|        | -0.09 (-0.15 – -0.07) ** 0.001 |
|        | -0.13 (-0.19 – -0.07) *** <0.001 |
|        | -0.12 (-0.19 – -0.04) 0.002 |
| Older siblings (ref = no) | 494  |
|        | -0.07 (-0.59 – -0.45) 0.794 |
|        | -0.01 (-0.45 – -0.43) 0.958 |
|        | 0.55 (0.06 – 1.04) * 0.029 |
|        | 0.55 (0.08 – 1.03) * 0.024 |
|        | -0.33 (-0.79 – -0.14) 0.173 |
|        | -0.25 (-1.37 – 1.13) 0.518 |
| Sleep duration | 365  |
|        | 0.09 (-0.12 – 0.3) 0.411 |
|        | -0.11 (-0.28 – 0.06) 0.217 |
|        | 0.01 (-0.18 – -0.2) 0.932 |
|        | 0.1 (-0.09 – 0.29) 0.317 |
|        | 0.07 (-0.12 – -0.26) 0.451 |
|        | 0.35 (-0.11 – -0.80) 0.138 |
| Breastfeeding duration | 259  |
|        | 0.06 (-0.01 – -0.13) 0.101 |
|        | 0.03 (-0.02 – -0.09) 0.244 |
|        | -0.01 (-0.07 – -0.06) 0.877 |
|        | 0.02 (-0.04 – -0.07) 0.601 |
|        | 0.01 (-0.05 – -0.07) 0.645 |
|        | -0.04 (-0.12 – -0.05) 0.427 |
| Overweight (ref = no) | 767  |
|        | 0.04 (-0.79 – -0.86) 0.927 |
|        | -0.37 (-1.08 – -0.34) 0.309 |
|        | -0.10 (-0.87 – -0.69) 0.812 |
|        | 0.20 (-0.56 – -0.96) 0.608 |
|        | 0.42 (-0.34 – -1.19) 0.279 |
|        | -1.39 (-3.12 – -0.34) 0.117 |

*p < .05, **p < .01, ***p < .001

a The tracing subtest is only conducted with children aged 42 months and older, resulting in smaller samples.

b Significant interaction with child age, c Significant interaction with child sex.

All associations were adjusted for age and sex.

All significant associations, except the association between hand motor skills and older siblings, stayed significant after adjusting for SES and gestational age.
Interaction effects of child age and sex

In accordance with our hypotheses, we assessed whether or not associations between developmental outcomes and gestational age, SES, and sex differed depending on child age. In the case of SES, significant interactions with age indicated that the positive associations with cognition and language skills were stronger in older children vs. younger children (b = .05 and .06, p = .008 and <.001, respectively). Other significant interactions showed that the associations between gestational age and body and hand motor skills became weaker as child age increased (b = -.07 and -.11, p = .018 and <.001, respectively). Finally, the negative associations between male sex and body or hand motor skills were stronger in older children compared to younger children (both b = -.23, p = .034 and .033, respectively).

We also assessed whether the association between developmental outcomes and gestational age differed between boys and girls. A significant interaction indicated that the association between higher gestational age and better hand motor skills was stronger in boys than in girls (b = .18, p = .036, see Figure 3).

DISCUSSION

The aim of our study was to explore risk and protective factors for early childhood development in a sample of healthy German children under 6 years of age. As expected for a sample of healthy children, mean development test scores were fairly close to the average for German children. It turned out that our sample contained an above-average number of children from families with high SES.

Factors associated with child development

We found positive significant associations between children's development and higher gestational age, higher SES, and the presence of older siblings. Negative significant associations were found between the performance in some of the developmental domains and male sex and behavioral difficulties. There was no evidence of an association between child development and duration of breastfeeding, average sleep duration, or overweight/obesity.

The results regarding gestational age are in line with our expectations. As in other studies, higher gestational age was associated with better development in cognition, language, hand and body motor skills, and social-emotional development.[3,5,8] These differences might be due to
structural brain alterations in preterm infants associated with the disruption of brain growth and maturation in the womb.[61] Regarding hand motor skills, the association with gestational age was stronger in boys than girls. This confirms the results of previous studies[7–9] and indicates that boys born prematurely are at particularly high risk for developmental delays. A generally higher vulnerability to adverse outcomes has been observed in preterm boys, which has yet to be explained.[62] In line with our hypotheses, the association between gestational age and development became weaker with increasing age. This result indicates that the development of children at age 6 is not as affected by gestational age as at earlier age (e.g. 0.5 years). This finding is similar to the result of Zambrana et al. who, however, only investigated language development.[4] In our study, the interaction effect with child age was significant only in the motor domains. Even if the same trend could be observed in the other developmental domains, this might imply that developmental delays in prematurely born children are more difficult to catch up in the areas of cognition, language and social-emotional skills than in the area of motor skills. When interpreting the results regarding gestational age, it must be noted that our sample contains mainly children born at term and few children with very low gestational age.

As expected, we observed significant positive associations between SES and development in all areas except hand motor skills. This is in line with the results of other studies.[14–17] A possible explanation is that a higher SES is associated with more child enrichment, i.e. with home and social activities conducive to development, e.g. regular reading of books or outdoor activities, which, in turn, might improve child development.[15] As hypothesized, our analysis suggests that the association between SES and development becomes stronger as children grow older, especially regarding cognitive and language development. This result is also consistent with the findings of other studies.[16–18] It seems plausible to consider SES as a social factor that has a greater impact the longer one is exposed to it. A study conducted in Germany suggests that this impact then remains fairly stable over the school years.[16] It is possible, thus, that schools can at least partially compensate for SES differences.[16,63]

In line with the results of other studies, girls performed better than boys in all developmental areas.[22,23,26] The differences were significant only in the areas of hand motor skills, tracing, and, more surprisingly, body motor skills. In other studies, girls tended to have greater advantages in all developmental domains except body motor skills.[22,23,26] The strongest evidence from other studies is on better language skills in girls than in boys.[24,64] The
mechanisms underlying the differences are probably multiple, and two reviews about cognitive or linguistic sex differences, respectively, conclude that biological and environmental factors combine to account for these outcomes, interacting and conditioning each other.[25,65] Interestingly, our analyses revealed that the observed sex differences became stronger with increasing age. This result is consistent with the tendencies reported in Krogh and Vaever's study,[23] but contradicts other studies that found that differences between males and females were smaller or non-existent in older as compared to younger (preschool) children.[24,66] We had expected widening developmental differences between boys and girls with increasing age due to the effects of gender socialization. This trend can also be observed in the differing emotional expression of boys and girls.[67] However, it is questionable whether this explanation can be applied to our rather surprising results in the area of motor development.

We found significant associations between cognitive development, hand motor skills, social-emotional development, and tracing with behavioral difficulties. Other studies also showed these associations.[30,31,68] These findings are highly relevant as children who have both behavioral and developmental problems are at particular risk of poor school performance.[31] Our results showed a positive association between having an older sibling and motor development (hand and body motor skills). This result supports the thesis of Barr and Hayne that children learn by imitating their older siblings,[69] at least with regard to motor development. We did not find significant associations in the other developmental domains. However, we did not consider the age gap between siblings or how much time they spent together. Large age gaps and little time together might limit the possibility to learn from each other.

None of the developmental domains were associated with average sleep duration. These results are consistent with the findings of some previous studies,[37,39–41] but contradict other studies that showed associations between sleep and child development.[36,38] Importantly, while several studies have found a negative association between sleep deprivation and executive functioning or reaction time,[70,71] only a few studies found an association between sleep and more general development. Therefore, one might cautiously conclude that sleep deprivation has a short-term effect on performance in cognitively demanding tasks, but no medium- or long-term effect on child development.

Similar to sleep, we observed no significant association between development and breastfeeding duration. In the ongoing debate on this topic, our results thus support the assumption that a potential positive association between development and breastfeeding is not
causally related to breastfeeding but rather caused by the fact that well-educated and socioeconomically advantaged women breastfeed longer than less-educated women.[43,44] In line with this assumption, an association could not be seen in our sample of middle-to-high SES families.

In addition to sleep and breastfeeding and as expected, overweight/obesity was not related to child development. This contradicts the results of a study with children below 4 years of age.[50] However, it is in line with the results of studies on older children, which also found no significant association between overweight/obesity and cognitive development or school performance.[48,49]

**Strengths and limitations**

Our study has some weaknesses. We studied a sample with above-average SES, which is thus relatively homogeneous and not representative of the whole population. This could lead to an underestimation of low SES as a risk factor for child development. Our sample sizes vary by factor studied (min = 259 children), so the strength of our large sample does not apply to each of the analyses.

**Conclusion**

Low gestational age, low SES, being a boy, and behavioral difficulties are risk factors for healthy and age-appropriate development, and their importance changes during child development. Having older siblings may improve motor development in children, while sleep duration, breastfeeding duration, and overweight/obesity do not seem to affect the development of children below school age. The development of children growing up under risk conditions should be monitored, bearing in mind that children may be affected by several risks at the same time. The best strategies to address the developmental risks must be well reflected in order to avoid possible discrimination or stereotyping through interventions themselves.
Acknowledgments

We would like to thank all LIFE Child research assistants for their efforts and the children and parents for their participation in the LIFE Child study.

Competing interests

The authors declare that they have no conflict of interest.

Funding statement

This publication is supported by LIFE – Leipzig Research Center for Civilization Diseases, University of Leipzig. LIFE is funded by means of the European Union, by means of the European Social Fund (ESF), by the European Regional Development Fund (ERDF), and by means of the Free State of Saxony within the framework of the excellence initiative.

Funded by the Open Access Publishing Fund of Leipzig University supported by the German Research Foundation within the program Open Access Publication Funding.

Author’s contributions

CS, WK, and TP contributed to conception and design of this study and to interpretation of data. CS, CM and TP contributed to acquisition of data and analysis. CS and TP wrote the original draft and CM, JK and WK revised it critically. All authors gave their final approval for this version to be published.

Data sharing statement

The datasets generated and/or analyzed during the current study are not publicly available due to ethical restrictions. The LIFE Child study is a study collecting potentially sensitive information. Publishing data sets is not covered by the informed consent provided by the study participants.

Furthermore, the data protection concept of LIFE requests that all (external as well as internal) researchers interested in accessing data sign a project agreement. Researchers that are interested in accessing and analyzing data collected in the LIFE Child study may contact the data use and access committee (forschungsdaten@medizin.uni-leipzig.de).

Trial registration

The LIFE Child study is registered on clinicaltrials.gov with the number NCT02550236.
Ethics approval

The LIFE Child study is conducted in accordance with the Declaration of Helsinki, and the study protocol has been approved by the Ethics Committee of the University of Leipzig (Reg. No. 264/10-ek).

Strengths and limitations of this study

- The large sample size (n = 778) and wide age range (0.5 – 6 years) of our sample allowed us to compare associations in different age groups.

- Development was measured directly by trained study personnel using a standardized test to establish objectivity.

- We included many different influencing factors and different aspects of development, including previously little studied areas such as motor skills or social-emotional development.

- We studied a sample with above-average SES, which is thus relatively homogeneous and not representative of the whole population.

- Our sample sizes vary by factor studied (min = 259 children), i.e. the strength of our large sample does not apply to each of the analyses.
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Figure 1 - Flow chart of participant selection. ET-6-6-R: Entwicklungstest für Kinder von 6 Monaten bis 6 Jahren (“Development Test for Children between 6 Months and 6 Years – Revision”); SES: socioeconomic status.

Figure 2 - Distribution of scores in the different developmental domains (n = 778).

Figure 3 - Effect plot illustrating the association (+ 95% CI) between gestational age and hand motor skills in girls and boys (n = 778).
1319 datasets of participations in the ET 6-6-R

- 499 excluded due to participation more than once

820 datasets of one visit per child

- 42 excluded due to missing data in ET-6-6-R, SES, and gestational age

778 children with complete data were included in the analyses
# STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cross-sectional studies

| Section/Topic | Item # | Recommendation | Reported on page # |
|---------------|--------|----------------|-------------------|
| **Title and abstract** | 1 | (a) Indicate the study's design with a commonly used term in the title or the abstract | 1 |
| | | (b) Provide in the abstract an informative and balanced summary of what was done and what was found | 2 |
| **Introduction** | 2 | Explain the scientific background and rationale for the investigation being reported | 3-5 |
| **Objectives** | 3 | State specific objectives, including any prespecified hypotheses | 5 |
| **Methods** | 4 | Present key elements of study design early in the paper | 5 |
| **Study design** | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | 5,6 |
| **Setting** | 6 | (a) Give the eligibility criteria, and the sources and methods of selection of participants | 6 |
| **Participants** | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | 6-8 |
| **Variables** | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | 6-8 |
| **Data sources/measurement** | 9 | Describe any efforts to address potential sources of bias | |
| **Bias** | 10 | Explain how the study size was arrived at | 6 |
| **Study size** | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | 6-8 |
| **Quantitative variables** | 12 | (a) Describe all statistical methods, including those used to control for confounding | 8 |
| **Statistical methods** | 13 | (b) Describe any methods used to examine subgroups and interactions | 8 |
| | | (c) Explain how missing data were addressed | 6 |
| | | (d) If applicable, describe analytical methods taking account of sampling strategy | |
| | | (e) Describe any sensitivity analyses | |
| **Results** | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed |
| --- | --- | --- |
|  |  | (b) Give reasons for non-participation at each stage |
|  |  | (c) Consider use of a flow diagram |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders |
|  |  | (b) Indicate number of participants with missing data for each variable of interest |
| Outcome data | 15* | Report numbers of outcome events or summary measures |
| Main results | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included |
|  |  | (b) Report category boundaries when continuous variables were categorized |
|  |  | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses |

**Discussion**

| Key results | 18 | Summarise key results with reference to study objectives |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results |

**Other information**

| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based |

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.
Associations between socio-demographic and behavioral parameters and child development depending on age and sex: A cross-sectional analysis

| Journal: | BMJ Open |
|----------|----------|
| Manuscript ID: | bmjopen-2022-065936.R1 |
| Article Type: | Original research |
| Date Submitted by the Author: | 06-Sep-2022 |
| Complete List of Authors: | Schild, Clara; Leipzig University, LIFE Leipzig Research Center for Civilization Diseases
Meigen, Christof; Leipzig University, LIFE Leipzig Research Center for Civilization Diseases
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| Primary Subject Heading: | Paediatrics |
| Secondary Subject Heading: | Public health, Sociology |
| Keywords: | PAEDIATRICS, Developmental neurology & neurodisability < PAEDIATRICS, Community child health < PAEDIATRICS, SOCIAL MEDICINE, PUBLIC HEALTH |
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Associations between socio-demographic and behavioral parameters and child development depending on age and sex: A cross-sectional analysis

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Word count: 4280

Keywords: child development, socioeconomic status, gestational age, cognitive development, language development
ABSTRACT

Objectives To explore environmental and individual factors that are associated with child development and to investigate whether the strength of these associations differs according to the age of the children.

Design Cross-sectional study

Setting This study was part of the LIFE Child study, a large cohort study conducted in Leipzig, Germany.

Participants 778 children aged between 0.5 and 6 years (48.6% female, mean age = 2.67 years).

Outcome measures The outcomes were cognitive development, language development, body and hand motor skills, social-emotional development, and tracing skills, measured with a standardized development test. We analyzed the associations between development and gestational age, socioeconomic status (SES), sex, behavioral difficulties, siblings, sleep duration, breastfeeding duration, and overweight/obesity. We also tested for interactions between these variables and child age or sex.

Results Higher gestational age (b ranging between .12 and .26) and higher SES (b ranging between .08 and .21) were associated with better outcomes in almost all developmental domains (all p < .019). Children with older siblings had improved body and hand motor skills compared to children without older siblings (both b = .55, all p < .029). Boys had poorer scores than girls in body and hand motor skills and tracing (b = -.45, -.68, and -1.5, all p < .019). Children with behavioral difficulties had significantly poorer outcomes in most developmental domains. Some of the associations with SES and sex were stronger in older than in younger children. Associations between gestational age and motor development were weaker in older children. We did not find significant associations between child development and sleep duration, breastfeeding duration, or overweight/obesity.

Conclusion Some factors had a protective, others an adverse effect on development of children under 6 years of age. The effect of SES and sex increased, while the effect of gestational age decreased with age.
STRENGTHS AND LIMITATIONS OF THIS STUDY

- The large sample size (n = 778) and wide age range (0.5–6 years) of our sample allowed us to compare associations in different age groups.

- Development was measured directly by trained study personnel using a standardized test to establish objectivity.

- We included many different influencing factors and different aspects of development, including previously little studied areas such as motor skills or social-emotional development.

- We studied a sample with above-average SES, which is thus relatively homogeneous and not representative of the whole population.

- Our sample sizes vary by factor studied (min = 259 children), i.e. the strength of our large sample does not apply to each of the analyses.
INTRODUCTION

In the first 6 years of life, i.e., in the phases of infancy, toddlerhood, and early childhood, cognitive, language, and motor skills develop particularly quickly.[1]

In sociocultural theories of development, e.g., Vygotsky's concept of the zone of proximal development or ecological systems approaches such as Bronfenbrenner's ecological framework for human development,[1] great importance is attached to children's (social) environment. In addition to the social environment, early child development might also be shaped by complications during and before birth, the presence of siblings, and the education, income, and behavior of the parents.[1] Other theories describe the developmental process in stages, e.g., Piaget's stages of cognitive development or Erikson's stages of psycho-social development. We look at possible influencing factors and their perhaps changing effect over a period of time that includes several of these developmental stages (sensorimotor and preoperational stage according to Piaget, or trust versus mistrust, autonomy versus shame and doubt, initiative versus guilt according to Erikson).[1] Because early development is influenced by so many factors and shapes later development,[2] it is particularly relevant to developmental research.

Low gestational age at birth is a major developmental risk for children.[3] Children born prematurely (<37th week of gestation) are at increased risk for developmental delays in cognition, language, motor skills, and social-emotional development.[4–6] In general, the earlier children are born, the greater their developmental disadvantages.[7] This phenomenon is stronger in boys than in girls.[8–10] Two studies even showed a slightly increased risk of language delay,[5] or scoring below average in a developmental screening test,[7] in children born mature but before 39 weeks of gestation. While some longitudinal studies show that developmental deficits, e.g., language delay, differences in cognition or achievement decrease or disappear as children grow older (at least in children born after the 34th week of gestation),[5,11] other studies show that differences in academic performance between preterm and term-born infants exist even at school age.[12,13]

The relationship between a family's socioeconomic status (SES) and their children's development has been examined for decades.[14] Children from poorer social backgrounds were found to show developmental delays[15,16] from as early as 7 months of age.[17] Several studies have shown that these disadvantages increase over childhood.[17,18] In line with this assumption, several studies showed an increased risk for achievement gaps in school between children from low- and high-SES families.[14,17,19]
In studies on associations between child development and potential risk factors (e.g., social disadvantages, maternal depression) in under 6 year olds, it was repeatedly noticed that girls performed better than boys in developmental tests on language, cognition, motor skills and social-emotional development.[15,20–22] In Krogh and Væver's study, girls already showed better fine motor skills at 7 months of age.[23]

There is already a large body of research on the relationship between poor language development and behavioral difficulties, such as internalizing or externalizing problems, inattention, or hyperactivity.[24–26] The data on other developmental domains (cognition, motor development) is more limited, although negative associations were also found in these domains.[27,28]

As children usually spend a lot of time with their siblings and as interactions with older or younger children might affect their own development, several scientists queried an association between the presence of siblings and children's development.[29] However, previous study results showed a mixed picture. In some studies, the presence of siblings was negatively associated with the development of communicative, cognitive, gross motor, and personal-social skills.[22,30] Other studies observed positive associations, especially regarding (fine) motor skills.[31,32]

Poor sleep quantity and quality might also be associated with developmental delays.[33] In experimental studies in which children were exposed to sleep restriction, weaker performance was observed in demanding cognitive tasks, reaction time measures, and working memory.[34] Studies examining the effects of different sleep patterns on children's cognitive, language, and academic performance revealed mixed results.[34,35] In some studies, children who slept less or later showed weaker performance.[36–38] However, other studies found no significant association between sleep duration[39,40] or sleep disruptions[40,41] and development.

Breastfeeding has many positive effects on infant health,[42] but there is controversy about the relationship between breastfeeding and cognitive development. While many studies showed a positive effect of breastfeeding, there is also some evidence that this effect is largely caused by confounders, most notably maternal socioeconomic status and intelligence.[43] Few studies examined sibling cohorts to exclude as many confounders as possible. One found no significant developmental differences between the breastfed children and their non-breastfed siblings.[44] In another study, the developmental advantages of breastfed infants remained significant even among discordant sibling pairs.[45]
As overweight and obesity have a high prevalence among children and adolescents in Germany (15.4% of 3- to 17-year-olds),[46] it is important to investigate possible effects on health and development. However, so far there is little evidence for a direct effect of being overweight/obese on cognitive development or academic performance. In one study, boys with overweight had weaker math and literacy skills compared to normal-weight peers, while no significant differences were found in girls.[47] Several studies found no significant effect of overweight/obesity on cognition or academic achievement at all.[48,49] Interestingly, a study on this topic in very young children aged 6 to 24 months found significantly lower scores among children with overweight/obesity in the cognitive and motor domains compared to normal-weight children.[50]

The aim of the present study is to investigate the associations of gestational age, SES, child sex, behavioral difficulties, siblings, sleep duration, breastfeeding, and overweight/obesity with the development of German children. Many of the previous studies on early child development examined only one of the influencing variables and its effect on a single developmental domain at a given age point. Our relatively large sample of 778 children includes children of all ages between 6 months and 6 years and consists of recently collected data (September 2016 to October 2020). This allows us to take a look at child development over the entire preschool period. We take into account multiple influencing factors and their effects on the different developmental domains of cognition, language, body and hand motor skills, and social-emotional development. Based on the results of previous studies, we expected higher gestational age, higher SES, longer average sleep duration, and longer breastfeeding duration to be positively associated with child development. We suspected poorer development for boys compared to girls, for children with older siblings, and for children showing more behavioral difficulties. We expected no differences in development if children were overweight/obese.

A specific focus was put on possible changes in the strengths of associations depending on child age. We hypothesized the association between SES or sex and development to be more pronounced in older children. In contrast, we expected the association between gestational age and development to be stronger in younger children. We further expected the association between development and gestational age to be more pronounced in boys than girls.
METHODS

Participants and Design

Data collection was conducted as part of the LIFE Child study. The LIFE Child study is a large population-based cohort study conducted at the Research Center for Civilization Diseases, Leipzig University. The study focuses on the physical and psychological development of healthy children from the prenatal phase to the age of 20.[51,52] Study participants are recruited since 2011 at public health centers, hospitals, and by word of mouth. In our analysis, we included all children between 0 and 6 years of age who performed the development test as part of the study program and whose parents provided information on their SES and the gestational age of their children. Data were cross-sectional and only one data point of each child was included. The cross-sectional design was chosen in favor of a larger sample size. If children had participated more than once, only the last visit was taken into account. Data was collected between September 2016 and October 2020. The final sample consisted of 778 0.35 - to 5.63-year-old children with complete developmental tests (48.6 % female, mean age = 2.67 years, see Figure 1). Data on variables collected through questionnaires were all provided by the accompanying parents of the children (completed on a computer screen during the study day). All questions included in the analysis are listed in a supplementary file. Due to specific missings in the parent-reported questionnaires, the sample size was smaller for some analyses (min = 259 children aged 0.88 to 5.9 years, see Table 1).

Measures

Development Test

In order to assess the development of the children, we applied the revised version of the Entwicklungstest 6 Monate – 6 Jahre (“Development Test for Children between 6 Months and 6 Years – Revision”, ET 6-6-R).[53] This standardized test for children between 6 months and 6 years of age assesses the developmental stage regarding cognition, language, body and hand motor skills as well as social-emotional skills. Children older than 42 months also complete a tracing subtest. Information on social-emotional development is collected through a questionnaire completed by parents. The other domains are assessed using age-specific standardized test items. The number of successfully completed items is converted into a developmental quotient (M = 10, SD = 3), based on age-specific references.[53] The reliability of the test was assessed with internal consistencies between $\alpha = .66$ and .77 depending on the
scale studied.[53] Clinical validity was demonstrated by significant correlations of the language and cognitive scales with child IQ,[54] by good discrimination between healthy children and children with stroke, and by significant correlations with the Bayley Scales of Infant Development II.[55,56] The ET 6-6-R is administered on an additional study day by trained study assistants.

Socioeconomic status (SES)

A family’s SES was determined on the basis of a parental questionnaire originally developed for the “Studie zur Gesundheit von Kindern und Jugendlichen in Deutschland” (Study on the health of children and adolescents in Germany, KiGGS).[57] The questionnaire collects data on parental education, occupational status, and equivalent household income.[57] Information on these three parameters is combined to an SES index ranging between 3 (indicating low SES) and 21 (indicating high SES). Based on cut-off values created in a large representative German sample, the SES index can be categorized as reflecting either low, middle, or high family SES. In a representative sample, the distribution of low-middle-high would be expected to be 20%-60%-20%.[57]

Behavioral strengths and difficulties

The parent version of the Strengths and Difficulties Questionnaire (SDQ) was used to assess behavioral strengths and difficulties in children aged 3 years and older.[58,59] This screening questionnaire comprises five scales, namely emotional problems, hyperactivity/inattention, peer relationship problems, conduct problems, and prosocial behavior. The results of the four different problem scales (all scales but prosocial behavior) can be combined into a total difficulties score, which ranges from 0 to 40, with higher scores indicating more behavioral difficulties.[58] This score was used for further analysis. In the representative norming sample of the German version of the SDQ, the internal consistency was $\alpha = .82$.[59]

Overweight/Obesity

Height and weight of all participants were measured by trained study assistants. BMI was calculated and converted to standard-deviation scores (BMI-SDS) using age- and gender-
specific percentiles for German children.[60] For data analysis, BMI-SDS was categorized as either normal weight (≤ 90th percentile) or overweight/obesity (>90th percentile).[60]

**Sleep duration**

Information on sleep habits was collected using parent questionnaires. For children up to 2 years of age, the Brief Infant Sleep Questionnaire (BISQ) was used.[61] For older children, we applied the Children’s Sleep Habits Questionnaire (CSHQ).[62] From both questionnaires, only the information on sleep duration was considered (see supplementary file). The hours of sleep per day and night were summed to obtain the total sleep time.

**Breastfeeding, gestational age at birth, and siblings**

Information on breastfeeding was collected using a self-created parent questionnaire. Parents were asked to indicate how many months the child was breastfed, regardless of whether it was exclusively breastfed or not. In another questionnaire, parents provided information on the number of older siblings of the child. From this information, we created a binary variable that indicates whether a child has at least one older sibling or not. Information on gestational age at birth was taken from medical records.

**Analysis**

Data analysis was performed using the free statistics software R (version 4.0.4).[63] We applied linear mixed-effect models to explore associations between the influencing variables and the developmental outcomes in the different domains. Unlike simple linear models, these models allowed us to control for possible sibling relationships within the sample (package lmer). Moreover, all associations were adjusted for age and sex. The developmental quotients in the domains of cognition, language, body motor, hand motor, social-emotional development, and tracing were included as dependent variables. Gestational age, sex, SES, the presence of older siblings, overweight/obesity, sleep duration, breastfeeding duration, and total difficulties score were included as independent variables. Separate models were calculated for each independent variable.

Following our hypotheses, associations between developmental outcomes and gestational age, sex, and SES were checked for interactions with child age at examination. Furthermore,
associations between developmental outcomes and gestational age were checked for interaction with sex.

Assuming small effects ($R^2$ of 0.02) and a power of 0.80, regression analyses with one predictor require 390 participants for effects to reach statistical significance ($p < 0.05$).[64] For all associations, the level of significance was set at $\alpha = 0.05$.

**Patient and public involvement**

Study participants or members of the public were not involved in the design of this study. At regular public events organized by the LIFE Child study, such as open days, study participants and members of the public are invited to learn about our latest research findings.

**RESULTS**

**Description of the study sample**

For each variable, sample size and distribution within the sample are shown in Table 1. The majority of the families (51.9%) had high SES, 46.4% had medium SES, and 1.7% had low SES. 50 of 767 children (6.52%) were overweight or obese. Information on siblings was available for 494 children, of whom 269 (54.5%) had no older siblings. The average developmental quotients of the ET 6-6-R ranged from 9.4 (SD = 2.88) to 10.61 (SD = 2.68, see Figure 2), depending on the developmental domain, and thus correspond approximately to the average for German children.[53]
Table 1 - Characteristics of the sample.

|                          | n     | Distribution       |
|--------------------------|-------|--------------------|
| **Age (years)**          | 778   |                    |
| < 2 (Infancy & Toddlerhood) | 349   | (44.86 %)          |
| 2 - 6 (Early childhood)  | 429   | (55.14 %)          |
| **Sex**                  | 778   |                    |
| Female                   | 378   | (48.6 %)           |
| Male                     | 400   | (51.4 %)           |
| **Older siblings**       | 494   |                    |
| No                       | 269   | (54.5 %)           |
| Yes                      | 225   | (45.5 %)           |
| **Overweight/Obesity**   | 767   |                    |
| No                       | 717   | (93.48 %)          |
| Yes                      | 50    | (6.52 %)           |
| **SES status**           | 778   |                    |
| high                     | 404   | (51.9 %)           |
| middle                   | 361   | (46.4 %)           |
| low                      | 13    | (1.7 %)            |

|                          | Range | Mean (SD)         |
|--------------------------|-------|-------------------|
| **Age (years)**          | 0.35 – 5.98 | 2.67 (1.78) |
| **SES index**            | 6.9 – 21 | 15.52 (2.95) |
| **Gestational age (weeks)** | 24.29 – 42.14 | 39.48 (2.16) |
| **SDQ score**            | 0 – 26 | 8.52 (4.32) |
| **Sleep time (hours/day)** | 6 – 16.6 | 12.18 (1.7) |
| **Breastfeeding duration (months)** | 1 – 36 | 11.05 (5.4) |
| **Developmental quotient** | 778 |                    |
| Cognition                | 1 – 17 | 10.03 (2.97) |
| Language                 | 1 – 15 | 10.06 (2.65) |
| Body motor               | 1 – 17 | 9.4 (2.88) |
| Hand motor               | 1 – 16 | 10.14 (2.76) |
| Social-emotional         | 1 – 17 | 10.61 (2.68) |
| Tracing                  | 307   | 10.21 (2.99) |
Associations between social and individual factors and developmental outcomes

As expected, higher gestational age was associated with better development in the domains of cognition, language, body motor skills, hand motor skills, and social-emotional development (b ranging between .12 and .26, all p < .008, see Table 2). Only tracing was not significantly associated with gestational age (b = .05, p = .589).

Also in line with the hypotheses, a higher SES was significantly associated with the developmental outcomes in the domains of cognition, language, body motor skills, social-emotional development, and tracing (b ranging from .08 to .21, all p < .019). Only developmental scores in the domain of hand motor skills showed no significant association with SES (b = .06, p = .09).

As expected, boys scored lower than girls in all developmental domains. However, the differences only reached significance in the domains of body and hand motor skills (b = -.45 and -.68, p = .019 and <.001, respectively) and tracing (b = -1.5, p = <.001, see Table 2).

Compared to gestational age, SES, and sex, the other independent variables showed fewer significant associations with the developmental outcomes. Regarding behavioral difficulties, a higher total difficulties score was significantly associated with poorer performance in the areas of cognition, hand motor skills, social-emotional development, and tracing (b ranging between -.08 and -.13, all p < .018).

The presence of older siblings was significantly associated with better motor skills (both b = .55, both p < .029), but not with development in other domains (see Table 2).

The associations between developmental outcomes and sleep duration, breastfeeding duration, and overweight/obesity were not significant (see Table 2).
Table 2 - Associations of social and individual variables with developmental outcomes.

| N       | Cognition                     | Language                     | Body motor                  | Hand motor                  | Social-emotional | Tracing a |
|---------|-------------------------------|------------------------------|-----------------------------|-----------------------------|------------------|-----------|
|         | b (95% CI)                    | p                            | b (95% CI)                  | p                           | b (95% CI)      | p         |
|         |                               |                               |                             |                             |                  |           |
| Gestational age | 778  | 0.24 (0.15 – 0.33) *** | <0.001   | 0.19 (0.11 – 0.28) *** | <0.001   | 0.21 (0.12 – 0.30) b *** | <0.001   | 0.26 (0.17 – 0.34) b *** | <0.001   | 0.12 (0.03 – 0.21) **  | 0.008    | 0.05 (-0.12 – 0.21)   | 0.589   |
| SES Score | 778   | 0.12 (0.05 – 0.18) b ** | 0.001     | 0.12 (0.06 – 0.18) *** | <0.001   | 0.08 (0.02 – 0.15) *     | 0.013     | 0.06 (-0.01 – 0.12)     | 0.09      | 0.08 (0.01 – 0.15) *  | 0.019     | 0.21 (0.11 – 0.32) *** | <0.001   |
| Sex (ref = female) | 778  | -0.40 (-0.80 – 0.00)  | 0.050     | -0.31 (-0.65 – 0.04)  | 0.079     | -0.45 (-0.83 – 0.07) b * | 0.019     | -0.68 (-1.05 – 0.31) b *** | <0.001   | -0.26 (-0.63 – 0.10) | 0.157     | -1.50 (-2.14 – 0.86) *** | <0.001   |
| SDQ total-score | 391  | -0.08 (-0.15 – 0.01) *  | 0.018     | -0.03 (-0.09 – 0.03)  | 0.372     | -0.06 (-0.12 – 0.00)     | 0.067     | -0.09 (-0.15 – 0.04) ** | 0.001     | -0.13 (-0.19 – 0.07) *** | <0.001   | -0.12 (-0.19 – 0.04) | 0.002     |
| Older siblings (ref = no) | 494  | -0.07 (-0.59 – 0.45)  | 0.794     | -0.01 (-0.45 – 0.43)  | 0.958     | 0.55 (0.06 – 1.04) *     | 0.029     | 0.55 (0.08 – 1.03) *     | 0.024     | -0.33 (-0.79 – 0.14) | 0.173     | -0.25 (-1.37 – 1.13) | 0.518     |
| Sleep duration | 365  | 0.09 (-0.121 – 0.3)   | 0.411     | -0.11 (-0.28 – 0.06)  | 0.217     | 0.01 (-0.18 – 0.2)       | 0.932     | 0.1 (-0.09 – 0.29)     | 0.317     | 0.07 (-0.12 – 0.26) | 0.451     | 0.35 (-0.11 – 0.80) | 0.138     |
| Breastfeeding duration | 259  | 0.06 (-0.01 – 0.13)   | 0.101     | 0.03 (-0.02 – 0.09)   | 0.244     | -0.01 (-0.07 – 0.06)     | 0.877     | 0.02 (-0.04 – 0.08)     | 0.601     | 0.01 (-0.05 – 0.07) | 0.645     | -0.04 (-0.12 – 0.05) | 0.427     |
| Overweight (ref = no) | 767  | 0.04 (-0.79 – 0.86)   | 0.927     | -0.37 (-1.08 – 0.34)  | 0.309     | -0.10 (-0.87 – 0.69)     | 0.812     | 0.20 (-0.56 – 0.96)     | 0.608     | 0.42 (-0.34 – 1.19) | 0.279     | -1.39 (-3.12 – 0.34) | 0.117     |

*p < .05, **p < .01, ***p < .001

a The tracing subtest is only conducted with children aged 42 months and older, resulting in smaller samples.

b Significant interaction with child age, c Significant interaction with child sex.

All associations were adjusted for age and sex.

All significant associations, except the association between hand motor skills and older siblings, stayed significant after adjusting for SES and gestational age.
Interaction effects of child age and sex

In accordance with our hypotheses, we assessed whether or not associations between developmental outcomes and gestational age, SES, and sex differed depending on child age. In the case of SES, significant interactions with age indicated that the positive associations with cognition and language skills were stronger in older children vs. younger children ($b = .05$ and .06, $p = .008$ and <.001, respectively). Other significant interactions showed that the associations between gestational age and body and hand motor skills became weaker as child age increased ($b = -.07$ and -.11, $p = .018$ and <.001, respectively). Finally, the negative associations between male sex and body or hand motor skills were stronger in older children compared to younger children (both $b = -.23$, $p = .034$ and .033, respectively).

We also assessed whether the association between developmental outcomes and gestational age differed between boys and girls. A significant interaction indicated that the association between higher gestational age and better hand motor skills was stronger in boys than in girls ($b = .18$, $p = .036$, see Figure 3).

DISCUSSION

The aim of our study was to explore risk and protective factors for early child development in a sample of healthy German children under 6 years of age, i.e., in the phases of infancy, toddlerhood and early childhood.[1] As expected for a sample of healthy children, mean development test scores were fairly close to the average for German children. It turned out that our sample contained an above-average number of children from families with high SES.

Factors associated with child development

We found positive significant associations between children's development and higher gestational age, higher SES, and the presence of older siblings. Negative significant associations were found between the performance in some of the developmental domains and male sex and behavioral difficulties. There was no evidence of an association between child development and duration of breastfeeding, average sleep duration, or overweight/obesity.

The results regarding gestational age are in line with our expectations. As in other studies, higher gestational age was associated with better development in cognition, language, hand and body motor skills, and social-emotional development.[4,6,9] These differences might be due to
structural brain alterations in preterm infants associated with the disruption of brain growth and maturation in the womb.[65] Regarding hand motor skills, the association with gestational age was stronger in boys than girls. This confirms the results of previous studies[8–10] and indicates that boys born prematurely are at particularly high risk for developmental delays. A generally higher vulnerability to adverse outcomes has been observed in preterm boys, the etiology of which is still insufficiently explained.[66] Multiple mechanisms likely contribute to this. For example, in animal studies, males were more vulnerable to cell damage from oxidative stress.[67] Hormonal and immunological sex differences might also play a role.[68,69] In line with our hypotheses, the association between gestational age and development became weaker with increasing age. This result indicates that the development of children at age 6 is not as affected by gestational age as at earlier age (e.g. 0.5 years). This finding is similar to the result of Zambrana et al. who, however, only investigated language development.[5] In our study, the interaction effect with child age was significant only in the motor domains. Even if the same trend could be observed in the other developmental domains, this might imply that developmental delays in prematurely born children are more difficult to catch up in the areas of cognition, language and social-emotional skills than in the area of motor skills. When interpreting the results regarding gestational age, it must be noted that our sample contains mainly children born at term and few children with very low gestational age.

As expected, we observed significant positive associations between SES and development in all areas except hand motor skills. This is in line with the results of other studies.[15–18] A possible explanation is that a higher SES is associated with more child enrichment, i.e. with home and social activities conducive to development, e.g. regular reading of books or outdoor activities, which, in turn, might improve child development.[16] As hypothesized, our analysis suggests that during infancy, toddlerhood and early childhood, the association between SES and development becomes stronger as children grow older, especially regarding cognitive and language development. This result is also consistent with the findings of other studies.[17–19] It seems plausible to consider SES as a social factor that has a greater impact the longer one is exposed to it. A study of representative cohorts (sample sizes ranging from 1813 to 6191) of German children aged between 0 and 15 years examined the trajectories of SES-dependent achievement gaps and showed that these gaps emerge in the preschool years but remain fairly stable thereafter.[17] It is possible, thus, that schools can at least partially compensate for SES differences.[17,70]
In line with the results of other studies, girls performed better than boys in all developmental areas.[22,23,30] The differences were significant only in the areas of hand motor skills, tracing, and, more surprisingly, body motor skills. In other studies, girls tended to have greater advantages in all developmental domains except body motor skills.[22,23,30] The strongest evidence from other studies is on better language skills in girls than in boys.[71,72] The mechanisms underlying the differences are probably multiple, and two reviews about cognitive or linguistic sex differences, respectively, conclude that biological and environmental factors combine to account for these outcomes, interacting and conditioning each other.[73,74] Interestingly, our analyses revealed that the observed sex differences became stronger with increasing age. This result is consistent with the tendencies reported in Krogh and Vaever's study,[23] but contradicts other studies that found that differences between males and females were smaller or non-existent in older as compared to younger (preschool) children.[72,75] We had expected widening developmental differences between boys and girls with increasing age due to the effects of gender socialization. This trend can also be observed in the differing emotional expression of boys and girls.[76] However, it is questionable whether this explanation can be applied to our rather surprising results in the area of motor development.

We found significant associations between cognitive development, hand motor skills, social-emotional development, and tracing with behavioral difficulties. Other studies also showed these associations.[27,28,77] These findings are highly relevant as children who have both behavioral and developmental problems are at particular risk of poor school performance.[28] Our results showed a positive association between having an older sibling and motor development (hand and body motor skills). This result supports the thesis of Barr and Hayne that children learn by imitating their older siblings.[78] at least with regard to motor development. We did not find significant associations in the other developmental domains. However, we did not consider the age gap between siblings or how much time they spent together. Large age gaps and little time together might limit the possibility to learn from each other.

None of the developmental domains were associated with average sleep duration. These results are consistent with the findings of some previous studies,[37,39–41] but contradict other studies that showed associations between sleep and child development.[36,38] Importantly, while several studies have found a negative association between sleep deprivation and executive functioning or reaction time,[79,80] only a few studies found an association between sleep and more general development. Therefore, one might cautiously conclude that sleep deprivation has
a short-term effect on performance in cognitively demanding tasks, but no medium- or long-term effect on child development.

Similar to sleep, we observed no significant association between development and breastfeeding duration. In the ongoing debate on this topic, our results thus support the assumption that a potential positive association between development and breastfeeding is not causally related to breastfeeding but may be influenced by a woman's SES and educational level, suggesting that socioeconomically advantaged women may breastfeed longer than less educated women.[43,44] In line with this assumption, an association could not be seen in our sample of middle-to-high SES families.

In addition to sleep and breastfeeding and as expected, overweight/obesity was not related to child development. This contradicts the results of a study with children below 4 years of age.[50] However, it is in line with the results of studies on older children, which also found no significant association between overweight/obesity and cognitive development or school performance.[48,49]

**Strengths and limitations**

Our study has some weaknesses. We studied a sample with above-average SES, which is thus relatively homogeneous and not representative of the whole population. This could lead to an underestimation of low SES as a risk factor for child development. Our sample sizes vary by factor studied (min = 259 children), so the strength of our large sample does not apply to each of the analyses. Furthermore, some of the questionnaires constructed for the LIFE child study have not been validated. As a weakness of the cross-sectional design of our study, we cannot draw causal conclusions from our results.

**Conclusion**

Low gestational age, low SES, being a boy, and behavioral difficulties are risk factors for healthy and age-appropriate development, and their importance changes during child development. Having older siblings may improve motor development in children, while sleep duration, breastfeeding duration, and overweight/obesity do not seem to affect the development of children below school age. For future research, we suggest focusing on the mechanisms underlying the well-established associations. The knowledge gained in this and other studies must be shared with those entrusted with children and their development. This enables parents,
educators and pediatricians, among others, to monitor the development of children growing up in conditions of risk, bearing in mind that children may be affected by several disadvantages at the same time. The best strategies to address the developmental risks must be well reflected in order to avoid possible discrimination or stereotyping through interventions themselves. One possibility to reduce social disadvantages would be the introduction of early, comprehensive, free and high-quality institutional childcare. Moreover, high-frequency checks (home visits) by pediatricians for early identification and intervention in children at risk (e.g., prematurely born children) would be helpful.
Acknowledgments

We would like to thank all LIFE Child research assistants for their efforts and the children and parents for their participation in the LIFE Child study.

Competing interests

The authors declare that they have no conflict of interest.

Funding statement

This publication is supported by LIFE – Leipzig Research Center for Civilization Diseases, University of Leipzig. LIFE is funded by means of the European Union, by means of the European Social Fund (ESF), the European Regional Development Fund (ERDF), and by means of the Free State of Saxony within the framework of the excellence initiative.

Funded by the Open Access Publishing Fund of Leipzig University supported by the German Research Foundation within the program Open Access Publication Funding.

Author’s contributions

CS, WK, and TP contributed to the conception and design of this study and the interpretation of data. CS, CM, and TP contributed to the acquisition of data and analysis. CS and TP wrote the original draft and CM, JK and WK revised it critically. All authors gave their final approval for this version to be published.

Data sharing statement

The datasets generated and/or analyzed during the current study are not publicly available due to ethical restrictions. The LIFE Child study is a study collecting potentially sensitive information. Publishing data sets is not covered by the informed consent provided by the study participants.

Furthermore, the data protection concept of LIFE requests that all (external as well as internal) researchers interested in accessing data sign a project agreement. Researchers that are interested in accessing and analyzing data collected in the LIFE Child study may contact the data use and access committee (forschungsdaten@medizin.uni-leipzig.de).

Trial registration

The LIFE Child study is registered on clinicaltrials.gov with the number NCT02550236.
Ethics approval

The LIFE Child study is conducted in accordance with the Declaration of Helsinki, and the study protocol has been approved by the Ethics Committee of the University of Leipzig (Reg. No. 264/10-ek).
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Figure 1 - Flow chart of participant selection. ET-6-6-R: Entwicklungstest für Kinder von 6 Monaten bis 6 Jahren (“Development Test for Children between 6 Months and 6 Years – Revision”); SES: socioeconomic status.

Figure 2 - Distribution of scores in the different developmental domains (n = 778).

Figure 3 - Effect plot illustrating the association (+ 95% CI) between gestational age and hand motor skills in girls and boys (n = 778).
1319 datasets of participations in the ET 6-6-R

820 datasets of one visit per child

778 children with complete data were included in the analyses

499 excluded due to participation more than once

42 excluded due to missing data in ET-6-6-R, SES, and gestational age
VARIABLES COLLECTED THROUGH QUESTIONNAIRES

Sleep duration

Excerpt from the Brief Infant Sleep Questionnaire:

- How long does your child sleep at night (between 7pm and 7am)? - hours
- How long does your child sleep at night (between 7pm and 7am)? - minutes
- How long does your child sleep during the day (between 7am and 7pm)? - hours
- How long does your child sleep during the day (between 7am and 7pm)? - minutes

Excerpt from The Children’s Sleep Habits Questionnaire:

- Your child’s usual amount of sleep per day (total amount of sleep from night and day): hours
- Your child’s usual amount of sleep per day (total amount of sleep from night and day): minutes

Older Siblings

- Number of older siblings of the test person

Breastfeeding

- How long did you breastfeed your child in total? If you are still breastfeeding, please indicate until now. If you cannot remember, please leave the field blank!

For “The Strentghs and Difficulties Questionnaire” see:

- Goodman R. The Strengths and Difficulties Questionnaire: A Research Note. J Child Psychol Psychiatry 1997

For the Questionnaire on the Socioeconomic Status see:

- Lampert T, Müters S, Stolzenberg H, et al. Messung des sozioökonomischen Status in der KiGGS-Studie. Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz 2014
STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cross-sectional studies

| Section/Topic             | Item # | Recommendation                                                                                                                                                                                                 | Reported on page # |
|---------------------------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| Title and abstract        | 1      | (a) Indicate the study’s design with a commonly used term in the title or the abstract                                                                                                                         | 1                 |
|                           |        | (b) Provide in the abstract an informative and balanced summary of what was done and what was found                                                                                                           | 2                 |
| Introduction              |        |                                                                                                                                                                                                              |                   |
| Background/rationale      | 2      | Explain the scientific background and rationale for the investigation being reported                                                                                                                           | 4-6               |
| Objectives               | 3      | State specific objectives, including any prespecified hypotheses                                                                                                                                                | 6                 |
| Methods                   |        |                                                                                                                                                                                                              |                   |
| Study design              | 4      | Present key elements of study design early in the paper                                                                                                                                                    | 7                 |
| Setting                   | 5      | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection                                                                              | 7                 |
| Participants              | 6      | (a) Give the eligibility criteria, and the sources and methods of selection of participants                                                                                                                   | 7                 |
| Variables                 | 7      | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable                                                                          | 7-9               |
| Data sources/measurement  | 8*     | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group                                           | 7-9               |
| Bias                      | 9      | Describe any efforts to address potential sources of bias                                                                                                                                                      |                   |
| Study size                | 10     | Explain how the study size was arrived at                                                                                                                                                                      | 7 + Figure 1      |
| Quantitative variables    | 11     | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why                                                                                     | 7-9               |
| Statistical methods       | 12     | (a) Describe all statistical methods, including those used to control for confounding                                                                                                                          | 9-10              |
|                           |        | (b) Describe any methods used to examine subgroups and interactions                                                                                                                                              | 9                 |
|                           |        | (c) Explain how missing data were addressed                                                                                                                                                                     | 7                 |
|                           |        | (d) If applicable, describe analytical methods taking account of sampling strategy                                                                                                                            |                   |
|                           |        | (e) Describe any sensitivity analyses                                                                                                                                                                          |                   |

Results
| Section       | Item | Description                                                                                                                                                                                                 | Page, Table, Figure |
|---------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| Participants  | 13*  | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed                              | 7, Table 1, Figure 1|
|               |      | (b) Give reasons for non-participation at each stage                                                                                                                                                           |                     |
|               |      | (c) Consider use of a flow diagram                                                                                                                                                                             | Figure 1            |
| Descriptive data | 14*  | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders                                                                       | 10, Table 1         |
|               |      | (b) Indicate number of participants with missing data for each variable of interest                                                                                                                        | Table 1             |
| Outcome data  | 15*  | Report numbers of outcome events or summary measures                                                                                                                                                           | 10, Table 1         |
| Main results  | 16   | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | 12, Table 2         |
|               |      | (b) Report category boundaries when continuous variables were categorized                                                                                                                                     |                     |
|               |      | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period                                                                                           |                     |
| Other analyses | 17   | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses                                                                                                                  | 14                  |
| Discussion    | 18   | Summarise key results with reference to study objectives                                                                                                                                                      | 14                  |
| Limitations   | 19   | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias                                                    | 17                  |
| Interpretation| 20   | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence                                              | 17-18               |
| Generalisability | 21   | Discuss the generalisability (external validity) of the study results                                                                                                                                          | 17                  |
| Other information | 22   | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based                                                              | 19                  |

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.