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Association between duration of digital device use and concentration and developmental screening outcomes among children aged 3–5 years in five Early Childhood Education Centers in Bekasi City

Hubungan durasi penggunaan gadget dengan konsentrasi dan hasil skrining perkembangan anak usia 3–5 tahun di lima PAUD Kota Bekasi

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Abstract

Longer gadget use duration may reduce opportunities for interaction and play activities that support attention and child development. This study aimed to analyze the association between the duration of gadget use, concentration, and developmental screening outcomes in children aged 3–5 years. A cross-sectional study was conducted from January to March 2026 at five purposively selected early childhood education centers in Bekasi City, Indonesia. Of the 201 registered children, 184 gadget users who met the study criteria were included in the analysis. The duration of gadget use was assessed using caregiver reports. Concentration was evaluated using a 10-item observation checklist (high concentration: score ≥7), and developmental status was screened using the age-appropriate KPSP. Associations were analyzed using Firth logistic regression and multivariable logistic regression adjusted for age, sex, center, sleep duration, parental education, socioeconomic status, nutritional status, dietary patterns, and supervision by caregivers. The mean duration of gadget use was 1.79±0.83 hours/day, with excessive use (>1 hour/day) identified in 120 children (65.2%). Recommended duration use (≤1 hour/day) was significantly associated with high concentration (adjusted OR=15.57; p<0.001) and appropriate developmental screening outcomes (adjusted OR=3.39; p=0.004). An increase in duration showed a graded decline in the favorable outcomes. In conclusion, a longer gadget use duration was associated with lower concentration and less favorable developmental screening outcomes in children.

Keywords: Gadget use duration, concentration, developmental screening, preschool children, screen time

Abstrak

Durasi penggunaan gadget yang lebih lama dapat mengurangi kesempatan anak untuk berinteraksi dan melakukan aktivitas bermain yang berperan dalam mendukung perhatian serta perkembangan anak. Penelitian ini bertujuan menganalisis hubungan durasi penggunaan gadget dengan konsentrasi dan hasil skrining perkembangan anak usia 3–5 tahun. Metode, studi potong lintang dilakukan pada Januari–Maret 2026 di lima PAUD Kota Bekasi yang dipilih secara purposif. Dari 201 anak yang terdaftar, sebanyak 184 anak pengguna gadget yang memenuhi kriteria penelitian dianalisis. Durasi penggunaan gadget diperoleh melalui laporan pengasuh. Konsentrasi dinilai menggunakan lembar observasi 10 item (konsentrasi tinggi: skor ≥7), sedangkan perkembangan anak dinilai menggunakan KPSP sesuai usia. Analisis dilakukan menggunakan regresi logistik Firth dan regresi logistik multivariat dengan penyesuaian terhadap usia, jenis kelamin, PAUD, durasi tidur, pendidikan orang tua, status sosial ekonomi, status gizi, pola makan,

dan pendampingan pengasuh. Hasil, rerata durasi penggunaan gadget adalah 1,79±0,83 jam/hari, dengan penggunaan berlebih (>1 jam/hari) ditemukan pada 120 anak (65,2%). Penggunaan gadget sesuai rekomendasi (≤1 jam/hari) berhubungan signifikan dengan konsentrasi tinggi (OR=15,57; p<0,001) dan hasil skrining perkembangan yang sesuai (OR=3,39; p=0,004). Peningkatan durasi penggunaan gadget menunjukkan penurunan bertahap proporsi anak dengan hasil yang optimal. Kesimpulan, durasi penggunaan gadget yang lebih lama berhubungan dengan rendahnya konsentrasi dan hasil skrining perkembangan yang kurang optimal.

Kata Kunci: Durasi penggunaan gadget, konsentrasi, skrining perkembangan, anak prasekolah, waktu layar

Introduction

Digital media exposure among young children has increased due to the widespread use of smartphones and tablets in families. During the ages of 3–5 years, the development of attention, executive function, speech, and language abilities relies heavily on play experiences, two-way communication, adequate sleep, and social interactions. Prolonged screen time may displace these essential developmental activities, although its effects are also influenced by the quality of content, usage context, and supervision (McDaniel & Radesky, 2018; McNeill et al., 2019; Supanitayanon et al., 2020).

The World Health Organization recommends that sedentary screen time among children aged 2–4 years should not exceed one hour per day, with less screen time being preferable (World Health Organization, 2019). Similarly, the American Academy of Pediatrics recommends limiting screen exposure to approximately one hour per day for children aged 2–5 years, emphasizing high-quality content and parental co-viewing (American Academy of Pediatrics, 2016). These recommendations highlight that screen duration is not the only critical factor, as caregiver interaction and non-screen activities are fundamental sources of developmental stimulation for infants.

Several studies have demonstrated that higher screen exposure is associated with less favorable developmental outcomes in children. Mobile device use has been linked to expressive language delays, reduced vocabulary development, and communication difficulties (Asikainen et al., 2021; Rayce et al., 2024; van den Heuvel et al., 2019). Regarding attention-related outcomes, higher screen time among preschool children has been associated with increased inattention problems and poorer executive functioning (Fitzpatrick et al., 2025; McHarg et al., 2020; Tamana et al., 2019). However, variations in assessment instruments, age groups, content characteristics, supervision patterns, and family related factors have resulted in inconsistent findings.

In Indonesia, gadgets are frequently used as entertainment tools and strategies for calming children. Previous local studies have primarily examined the association between gadget use and language development or speech abilities, with variations in populations and measurement approaches (Anggrasari & Rahagia, 2020; Dewi et al., 2019; Dewi & Handajany, 2023; Putri & Soesyasmoro, 2023; Septyani et al., 2021). Meanwhile, concentration and multidomain developmental screening outcomes have rarely been simultaneously investigated among children attending five early childhood education (ECE) centers, locally known as *Pendidikan Anak Usia Dini* (PAUD) centers, using standardized assessment procedures. A preliminary study conducted in December 2025 among 20 children aged 3–5 years from two early childhood education centers in Bekasi City outside the study sites showed that 13 children (65.0%) used gadgets for more than one hour per day, nine children (45.0%) demonstrated low concentration during classroom observations, and seven children (35.0%) showed developmental or communication concerns based on initial screening and teacher/parent report. Unlike previous local studies that focused on a single developmental outcome, this study simultaneously evaluated concentration and developmental screening outcomes based on the total KPSP scores across five early childhood education centers.

Furthermore, this study provided center-specific estimates, exploratory dose–response patterns, and multivariable-adjusted estimates. Therefore, this study aimed to analyze the association between gadget use duration, concentration levels, and developmental screening outcomes among children aged 3–5 years in five early childhood education centers in Bekasi, Indonesia.

Methods

Study Design and Setting

This study used an analytical observational design with a cross-sectional approach. Data were collected from January to March 2026 at five early childhood education centers in Bekasi City: PAUD KB Mubina, PAUD SPS Gemini, PAUD Qur'an Al-Fatih YSBA, PAUD SPS Murni, and PAUD TPQ DTA & Wustho Baiturrahim.

The five centers were selected using purposive sampling based on the representativeness of early childhood education management characteristics, geographic distribution within Bekasi City, availability of an adequate number of children aged 3–5 years, and institutional willingness to participate as research sites. Because the site selection was purposive, the generalizability of the findings was limited to populations comparable to the five early childhood education centers.

Participants and Sampling

The accessible population consisted of 201 children aged 3–5 years enrolled in five early childhood education centers. Sample adequacy was justified using a finite population proportion estimation formula with a 95% confidence level (Z=1.96), a conservative proportion estimate of p=0.50, an absolute precision of 5%, and N=201. The calculation yielded a minimum required sample size of 132 children per group. After accounting for a 10% allowance for incomplete data or non-response, the minimum target sample size was 147.

Total sampling was applied to the entire accessible population. All children were screened according to the eligibility criteria of this study. Seventeen children were excluded from the analysis, including eight who did not use gadgets in daily life, four with diagnosed neurological, hearing, or developmental disorders, three who were absent during data collection, and two whose parents or guardians declined to participate. Therefore, 184 eligible children with complete data were included in the final analysis, exceeding the minimum required sample size. The final sample consisted of 40 children from PAUD KB Mubina, 36 from PAUD SPS Gemini, 39 from PAUD Qur'an Al-Fatih YSBA, 34 from PAUD SPS Murni, and 35 from PAUD TPQ DTA & Wustho Baiturrahim.

The inclusion criteria were as follows: children aged 3–5 years, enrolled in early childhood education activities, using gadgets in daily life, and having provided written informed consent from their parents or guardians. The exclusion criteria were diagnosed neurological disorders, hearing impairment, developmental disorders, absence during data collection, and incomplete data. Eight children who did not use gadgets were excluded from the primary analysis because the initial protocol required gadget use as an inclusion criterion, which was considered a potential source of selection bias.

Study Variables and Gadget Use Assessment

The independent variable was the duration of gadget use, and the dependent variables were concentration level and developmental screening outcomes. In this study, gadgets were defined as smartphones or tablets actively used by children; passive television exposure was excluded from the study. Gadget use duration included both educational and recreational use at home or outside structured early childhood education activities.

A parent-reported questionnaire consisted of four questions assessing smartphone/tablet use duration on school days and weekends during the previous seven days. The average daily duration was calculated using the following weighted formula: [(average weekday duration × 5) + (average weekend duration × 2)]/7. Gadget use duration was analyzed as a continuous variable (hours/day) and categorized according to recommendations as appropriate use (≤1 hour/day) and excessive use (>1 hour/day) (American Academy of Pediatrics, 2016; World Health Organization, 2019). For the exploratory dose–response analysis, duration was further categorized into ≤1.0, >1.0–2.0, >2.0–3.0, and >3.0 h/day.

Concentration Assessment

The concentration level was assessed by two trained observers using a 10-item checklist. The observers independently evaluated the children and were blinded to the results of the gadget duration questionnaire at the time of the observation. Each item was scored as 1 when a concentration-related behavior was observed and 0 when it was absent.

Observations were conducted for 20 min during structured learning activities using the same observation guidelines and core task sequence across all participating early childhood education centers. Each assessment was performed on two occasions. When discrepancies occurred between

observers, independent scores were initially retained for reliability analysis, and disagreements were discussed after the observation session to ensure consistent interpretation of the items. The final concentration score was calculated as the mean of the scores for each observation. The total score ranged from 0–10. Concentration was categorized as high when the score was ≥7 and low when the score was ≤6. The ≥7 cut-off was predetermined as an operational threshold representing the achievement of at least 70% of the concentration indicators based on expert consensus during the content validity assessment and pilot testing. However, this cutoff has not undergone external criterion validation; therefore, its interpretation remains limited to operational classification within this study.

Developmental Screening Assessment

Child development was assessed using the age-appropriate *Kuesioner Pra Skrining Perkembangan* (KPSP) by trained researchers, incorporating parental information and demonstrations of child-related tasks. The KPSP consists of 10 age-specific items covering gross motor, fine motor, speech-language, socialization, and independence domains.

Developmental screening classification was based on the total KPSP score: 9–10 "Yes" responses were categorized as appropriate, 7–8 as questionable, and ≤6 as possible developmental deviations. For the 2×2 association analyses, the questionable and possible deviation categories were combined into a single "inappropriate" category owing to limited observations within each early childhood education center. Because classification was based on a multidomain total score, the outcome was interpreted as a developmental screening status rather than a specific speech-language developmental outcome.

Instrument Validity and Reliability

The gadget duration questionnaire and concentration observation checklist were reviewed by six experts in pediatric nursing, child development, and early childhood education. The content validity assessment demonstrated an S-CVI/Ave of 0.90 for the gadget duration questionnaire and 0.92 for the concentration observation checklist, with I-CVI values ranging from 0.83–1.00.

A pilot study was conducted among 30 children from early childhood education centers outside the study sites. Internal consistency reliability yielded Cronbach's alpha values of 0.82 for the gadget duration questionnaire and 0.84 for the concentration observation checklist. The test–retest reliability of the gadget duration questionnaire demonstrated an intraclass correlation coefficient (ICC) of 0.88, whereas the interobserver agreement for concentration assessment showed a Cohen's kappa coefficient of 0.81. The KPSP was administered according to standardized guidelines and was not revalidated in the study sample.

Covariate Assessment

Individual-level covariates included in the multivariate analysis were obtained from parental questionnaires and child measurement records. Sleep duration was categorized as adequate when children slept 10–13 h per 24 h and insufficient when they slept below this range. Parental education was categorized as primary, secondary, or tertiary. Socioeconomic status was classified as low, middle, or high according to the income categories in the questionnaire.

Nutritional status was summarized as normal or abnormal based on anthropometric classifications from the children's measurement records. Dietary patterns were categorized as adequate or inadequate based on a dietary habit checklist, and caregiver supervision was recorded as the presence or absence of co-use or co-viewing. For the regression analysis, secondary/higher parental education was compared with primary education, and middle/high socioeconomic status was compared with a low socioeconomic status.

Statistical Analysis

Univariate analyses were performed using frequencies, percentages, means ± standard deviations, medians, and interquartile ranges according to data distribution and variable type. Because several 2×2 tables within individual early childhood education centers contained small frequencies and zero cells, center-specific associations were estimated using Firth logistic regression to reduce small-sample bias and produce finite odds ratio (OR) estimates (Arrué et al., 2016).

For the initial pooled analyses, the data were stratified by early childhood education center using the Cochran–Mantel–Haenszel method, and the OR homogeneity across centers was evaluated using the Breslow–Day test with Tarone adjustment. Exploratory dose–response patterns were assessed using four gadget duration categories and logistic regression with continuous duration per 1-hour/day increment.

Additional primary analyses were conducted using individual-level multivariable logistic regression models for each outcome. The primary exposure variable was the recommended duration of gadget use (≤1 h/day) compared with excessive use (>1 h/day). The models were adjusted for age, sex, early childhood education center as a fixed effect, sleep duration, parental education, socioeconomic status, nutritional status, dietary patterns, and caregiver supervision. Results are reported as adjusted odds ratios (aORs) with 95% confidence intervals (CIs). Statistical significance was set at $P < 0.05$.

Result and Discussion

A total of 184 children were included in the study. Children aged 5 years represented the largest age group (42.4%), and the proportions of boys and girls were relatively balanced. A total of 120 children (65.2%) used gadgets for more than one hour per day. The mean duration of gadget use was 1.79±0.83 hours/day, with a median of 2.00 hours/day (IQR: 0.85–2.46) and a range of 0.45–3.31 hours/day.

Overall, 91 children (49.5%) demonstrated high concentration levels, and 115 (62.5%) had appropriate developmental screening outcomes. Adequate sleep duration was observed in 111 (60.3 %) children. Parental education levels were categorized as primary (20.7%), secondary (49.5%), and higher (29.9%) education. Socioeconomic status was classified as low (28.3%), middle (51.1%), or high (20.7%). Most children had a normal nutritional status (75.5%), adequate dietary patterns (64.1%), and caregiver supervision during gadget use (54.3%).

Table 1. Characteristics of participants according to early childhood education center (n=184)

Early childhood education center	n	Age 3 years, n (%)	Age 4 years, n (%)	Age 5 years, n (%)	Boys, n (%)	Girls, n (%)
PAUD KB Mubina	40	14 (35.0)	11 (27.5)	15 (37.5)	20 (50.0)	20 (50.0)
PAUD SPS Gemini	36	13 (36.1)	9 (25.0)	14 (38.9)	19 (52.8)	17 (47.2)
PAUD Qur'an Al-Fatih YSBA	39	9 (23.1)	9 (23.1)	21 (53.8)	23 (59.0)	16 (41.0)
PAUD SPS Murni	34	9 (26.5)	15 (44.1)	10 (29.4)	17 (50.0)	17 (50.0)
PAUD TPQ DTA & Wustho Baiturrahim	35	8 (22.9)	9 (25.7)	18 (51.4)	15 (42.9)	20 (57.1)
Total	184	53 (28.8)	53 (28.8)	78 (42.4)	94 (51.1)	90 (48.9)

Distribution of Gadget Use Duration, Concentration, and Developmental Screening Outcomes

Across the five early childhood education centers, 64 children (34.8%) met the recommended gadget use duration (≤1 hour/day), and 120 children (65.2%) exceeded the recommended duration (>1 hour/day). A high concentration was observed in 91 children (49.5%), and 93 children (50.5%) demonstrated a low concentration. Developmental screening outcomes were appropriate for 115 children (62.5%), and 69 children (37.5%) were classified as having inappropriate screening outcomes.

Table 2. Distribution of gadget use duration, concentration level, and developmental screening outcomes according to early childhood education center (n=184)

Early childhood education center	Gadget use duration		Concentration level		Developmental screening	
	Recommended, n (%)	Excessive, n (%)	High, n (%)	Low, n (%)	Appropriate, n (%)	Inappropriate, n (%)
PAUD KB Mubina	12 (30.0)	28 (70.0)	23 (57.5)	17 (42.5)	27 (67.5)	13 (32.5)
PAUD SPS Gemini	13 (36.1)	23 (63.9)	16 (44.4)	20 (55.6)	24 (66.7)	12 (33.3)
PAUD Qur'an Al-Fatih YSBA	12 (30.8)	27 (69.2)	17 (43.6)	22 (56.4)	18 (46.2)	21 (53.8)
PAUD SPS Murni	13 (38.2)	21 (61.8)	15 (44.1)	19 (55.9)	18 (52.9)	16 (47.1)
PAUD TPQ DTA & Wustho Baiturrahim	14 (40.0)	21 (60.0)	20 (57.1)	15 (42.9)	28 (80.0)	7 (20.0)
Total	64 (34.8)	120 (65.2)	91 (49.5)	93 (50.5)	115 (62.5)	69 (37.5)

Developmental Screening Classification Based on KPSP Scores

The distribution of the three developmental screening categories showed that 115 children (62.5%) had appropriate developmental screening outcomes, 47 children (25.5%) were categorized as questionable, and 22 children (12.0%) were classified as having possible developmental delays.

Table 3. Distribution of three KPSP developmental screening categories according to early childhood education center (n=184)

Early childhood education center	Appropriate, n (%)	Questionable, n (%)	Possible developmental deviation, n (%)	Total
PAUD KB Mubina	27 (67.5)	9 (22.5)	4 (10.0)	40
PAUD SPS Gemini	24 (66.7)	8 (22.2)	4 (11.1)	36
PAUD Qur'an Al-Fatih YSBA	18 (46.2)	13 (33.3)	8 (20.5)	39
PAUD SPS Murni	18 (52.9)	11 (32.4)	5 (14.7)	34
PAUD TPQ DTA & Wustho Baiturrahim	28 (80.0)	6 (17.1)	1 (2.9)	35
Total	115 (62.5)	47 (25.5)	22 (12.0)	184

Association Between Gadget Use Duration and Concentration Level

Center-specific analyses using Firth logistic regression demonstrated that the recommended gadget use duration (≤1 hour/day) was associated with higher odds of high concentration across most early childhood education centers. Significant associations were observed for PAUD KB Mubina ($p<0.001$), PAUD SPS Gemini ($p<0.001$), PAUD Qur'an Al-Fatih YSBA ($p<0.001$), and PAUD SPS Murni ($p=0.003$). However, this association was not statistically significant for PAUD TPQ DTA and Wustho Baiturrahim ($p=0.175$).

In the pooled analysis stratified by early childhood education centers, the recommended duration of gadget use remained significantly associated with high concentrations ($p<0.001$).

Table 4. Association between gadget use duration and concentration level according to early childhood education center

Early childhood education center	Recommended		Excessive		p-value
	High, n (%)	Low, n (%)	High, n (%)	Low, n (%)	
PAUD KB Mubina	12 (100.0)	0 (0.0)	11 (39.3)	17 (60.7)	<0.001*
PAUD SPS Gemini	11 (84.6)	2 (15.4)	5 (21.7)	18 (78.3)	<0.001*
PAUD Qur'an Al-Fatih YSBA	12 (100.0)	0 (0.0)	5 (18.5)	22 (81.5)	<0.001*
PAUD SPS Murni	10 (76.9)	3 (23.1)	5 (23.8)	16 (76.2)	0.003*
PAUD TPQ DTA & Wustho Baiturrahim	10 (71.4)	4 (28.6)	10 (47.6)	11 (52.4)	0.175*
Pooled analysis	55 (85.9)	9 (14.1)	36 (30.0)	84 (70.0)	<0.001

Association Between Gadget Use Duration and Developmental Screening Outcomes

The association between gadget use duration and developmental screening outcomes differed across early childhood education centers. A statistically significant relationship between adherence to the recommended duration of gadget use and appropriate developmental screening outcomes was identified at PAUD KB Mubina ($p = 0.002$), PAUD Qur'an Al-Fatih YSBA ($p = 0.018$), and PAUD TPQ DTA & Wustho Baiturrahim ($p = 0.014$). In contrast, no significant associations were found for PAUD SPS Gemini ($p = 0.837$) or PAUD SPS Murni ($p = 0.145$).

These findings indicate some variation in the observed relationship across educational settings for the participating children. However, when the data were pooled and analyzed with stratification by early childhood education center, adherence to the recommended gadget use duration remained significantly associated with appropriate developmental screening outcomes ($p < 0.001$), suggesting that the overall association persisted after accounting for differences among centers.

Table 5. Association between gadget use duration and developmental screening outcomes according to early childhood education center

Early childhood education center	Recommended		Excessive		p-value
	Appropriate, n (%)	Inappropriate, n (%)	Appropriate, n (%)	Inappropriate, n (%)	
PAUD KB Mubina	12 (100.0)	0 (0.0)	15 (53.6)	13 (46.4)	0.002*
PAUD SPS Gemini	9 (69.2)	4 (30.8)	15 (65.2)	8 (34.8)	0.837*
PAUD Qur'an Al-Fatih YSBA	9 (75.0)	3 (25.0)	9 (33.3)	18 (66.7)	0.018*
PAUD SPS Murni	9 (69.2)	4 (30.8)	9 (42.9)	12 (57.1)	0.145*
PAUD TPQ DTA & Wustho Baiturrahim	14 (100.0)	0 (0.0)	14 (66.7)	7 (33.3)	0.014*
Pooled analysis	53 (82.8)	11 (17.2)	62 (51.7)	58 (48.3)	<0.001

Adjusted Associations Between Gadget Use Duration and Study Outcomes

In individual-level multivariable logistic regression models, the recommended duration of gadget use (≤1 hour/day) remained significantly associated with high concentration and appropriate developmental screening outcomes after adjusting for age, sex, early childhood education center, sleep duration, parental education, socioeconomic status, nutritional status, dietary patterns, and caregiver supervision.

Children with the recommended gadget use duration had substantially higher odds of demonstrating high concentration compared with those using gadgets for more than one hour per day (adjusted OR [aOR]=15.57; 95% CI: 6.35–38.19; p<0.001). Similarly, the recommended gadget use duration was associated with appropriate developmental screening outcomes (aOR=3.39; 95% CI: 1.48–7.75; p=0.004).

Adequate sleep duration was independently associated with appropriate developmental screening outcomes (aOR=2.07; 95% CI: 1.02–4.18; p=0.043). Other covariates, including age, sex, parental education, socioeconomic status, nutritional status, dietary pattern, and caregiver supervision, were not significantly associated with the outcomes of this study.

Table 6. Multivariable-adjusted associations between gadget use duration and concentration and developmental screening outcomes

Variable	High concentration aOR (95% CI)	p-value	Appropriate developmental screening aOR (95% CI)	p-value
Gadget duration ≤1 hour/day	15.57 (6.35–38.19)	<0.001	3.39 (1.48–7.75)	0.004
Age (per 1-year increase)	1.46 (0.93–2.30)	0.101	0.71 (0.46–1.09)	0.114
Female vs male	1.38 (0.65–2.94)	0.404	0.97 (0.48–1.97)	0.932
Adequate sleep duration	1.44 (0.69–3.02)	0.337	2.07 (1.02–4.18)	0.043
Secondary/higher parental education	0.83 (0.33–2.10)	0.696	1.22 (0.51–2.92)	0.653
Middle/high socioeconomic status	0.70 (0.31–1.58)	0.393	1.95 (0.92–4.14)	0.081
Normal nutritional status	1.19 (0.51–2.78)	0.695	0.72 (0.32–1.62)	0.426
Adequate dietary pattern	2.03 (0.94–4.41)	0.072	1.67 (0.81–3.46)	0.168
Caregiver supervision	0.86 (0.41–1.83)	0.695	1.48 (0.73–3.01)	0.272

Center-specific Firth logistic regression produced finite OR estimates; however, several confidence intervals remained wide, indicating limited precision owing to small sample sizes within the individual centers. In stratified analyses by early childhood education center, the recommended duration of gadget use was associated with high concentration (OR_{MH}=13.54; 95% CI: 5.92–30.97; p<0.001) and appropriate developmental screening outcomes (OR_{MH}=4.69; 95% CI: 2.16–10.19; p<0.001).

In the individual-level multivariable models (Table 6), these associations remained significant after adjustment for potential confounders, with aOR=15.57 (95% CI: 6.35–38.19; p<0.001) for

high concentration and aOR=3.39 (95% CI: 1.48–7.75; p=0.004) for appropriate developmental screening. The Breslow–Day test with Tarone adjustment indicated evidence of heterogeneity in ORs across early childhood education centers for concentration outcomes (p=0.041), whereas the evidence of heterogeneity for developmental screening outcomes was weaker (p=0.104).

This study found that nearly two-thirds of the children used gadgets for more than one hour per day, with an average duration of 1.79 hours per day. Exploratory analyses demonstrated a gradual decline in the proportion of children with high concentrations and appropriate developmental screening outcomes as gadget use duration increased. This pattern indicates a dose–response gradient between exposure and outcomes within the study data, although the cross-sectional design does not allow for determining the causal direction. Similar patterns have been reported in early childhood development studies, particularly when digital devices are primarily used for entertainment or as a strategy to calm children (Madigan et al., 2019; Muslikah et al., 2024). The availability of digital devices at home, parental screen behaviors, and inconsistent family media rules may contribute to the increased duration of gadget use in children (McDaniel & Radesky, 2018; McNeill et al., 2019).

After multivariate adjustment, the recommended gadget use duration remained strongly associated with higher concentration levels. The adjusted odds ratio was slightly higher than the Mantel–Haenszel estimate; however, the confidence interval remained wide, indicating that the magnitude of the association should be interpreted cautiously. This finding is consistent with previous cohort studies, including the CHILD cohort study, which reported that higher screen time during the preschool years was associated with greater inattention problems (Tamana et al., 2019), as well as longitudinal studies examining the associations between screen exposure and executive functioning development (Fitzpatrick et al., 2025; McHarg et al., 2020).

A possible explanation for this finding is the displacement hypothesis, which states that screen exposure replaces developmental experiences that promote sustained attention, such as active play, reciprocal communication, turn-taking activities, and problem-solving interactions. Excessive gadget use may reduce children's opportunities to engage in activities that require self-regulation and sustained attention. Although the present model incorporates several family and behavioral factors, residual confounding may still exist. Therefore, the adjusted odds ratios should not be interpreted as causal effects.

The association between gadget use duration and concentration varied across early childhood education centers, with the Breslow–Day test indicating potential heterogeneity (p=0.041). This finding should be interpreted as a possible variation in effect estimates rather than simply differences between statistically significant and non-significant results across individual centers. This variation may be influenced by small sample sizes within each center, differences in age and sex distribution, and unmeasured variations in sleep quality, content type, timing of gadget use, caregiver involvement, and the learning environment. Although Firth's logistic regression minimizes estimation problems caused by zero-event cells, the wide confidence intervals in several center-specific analyses indicate the limited precision of these estimates.

The recommended gadget-use duration was also associated with appropriate developmental screening outcomes after multivariate adjustment. However, this association was more moderate than that observed for the concentration. Adequate sleep duration was independently associated with appropriate developmental screening outcomes, highlighting the importance of broader lifestyle factors in early childhood development. Because the developmental outcome in this study was based on the multidomain total KPSP score, comparisons are most appropriate with those of studies examining general developmental screening or overall developmental outcomes. Madigan et al. (2019) reported a longitudinal association between screen time exposure and developmental screening performance, whereas McArthur et al. (2022) found that higher screen time was associated with less favorable developmental and behavioral outcomes in preschool children.

Previous studies focusing on language and communication outcomes remain relevant as supporting evidence but are not directly equivalent to the multidomain KPSP assessment used in this study's methodology. Research has reported associations between screen exposure and expressive language delay, lower vocabulary

development, and communication difficulties (Asikainen et al., 2021; Rayce et al., 2024; Takahashi et al., 2023; Van den Heuvel et al., 2019). These findings provide additional context regarding how digital media exposure may influence specific developmental domains, although the present study evaluated overall developmental screening status, rather than language-specific outcomes.

One possible mechanism underlying this association is the displacement of developmentally beneficial activity. Longer screen exposure may reduce the time available for two-way conversations, shared reading, symbolic play, physical activity, and social interactions. In addition, the quality of digital content and caregiver involvement during media use may modify children's experiences with technology (Supanitayanon et al., 2020). In the present multivariable analysis, parental education, socioeconomic status, nutritional status, dietary pattern, and caregiver supervision were not statistically significant after adjusting for other covariates. However, the absence of statistical significance does not exclude clinical relevance or the possibility of residual confounding, particularly given the limited sample size and measurement precision of several covariates.

This study had several limitations. The cross-sectional design limited our ability to establish temporal relationships and excluded any causal inferences. The gadget use duration and several covariates were based on parent-reported data, which may have introduced recall and social desirability biases. The purposive selection of early childhood education centers and exclusion of non-gadget users may limit the generalizability of the findings to other preschools. Residual confounding may remain due to the unavailability of information on digital content quality, family interaction patterns, and objective measurement of screen time. The small sample size within individual centers also resulted in imprecise estimates despite the use of Firth's logistic regression.

Conclusion

This study demonstrated that a shorter gadget use duration was significantly associated with higher concentration levels and more favorable developmental screening outcomes among children aged 3–5 years. Children who used gadgets within the recommended duration (≤1 h/day) had greater odds of achieving high concentration and appropriate developmental screening results after adjusting for individual- and family related factors. Although the cross-sectional design limits causal interpretation, the observed dose–response pattern highlights the potential importance of managing screen exposure during early childhood.

Parents, caregivers, and early childhood educators should promote age-appropriate screen time limits, prioritize interactive activities, and encourage adequate sleep and direct social interactions to support optimal child development. Future longitudinal and intervention studies are needed to clarify the causal relationships and evaluate the effectiveness of screen time reduction strategies.

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