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Original article

# Fundamental motor skills, screen-time, and physical activity in preschoolers

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## Abstract

*Purpose*: To examine the associations among preschoolers fundamental motor skills, screen-time, physical activity (PA), and sedentary behavior (SB).
*Methods*: Children ages 3−4 years were enrolled in a prospective observational trial of PA. Trained assessors conducted the Test of Gross Motor Development-3rd edition (TGMD-3), and the Movement Assessment Battery for Children-2nd edition, and parent-reported child screen-time and sociodemographic information. Children wore an accelerometer for 7 days to examine SB and total PA (TPA). TPA was further characterized as moderate-to-vigorous PA (MVPA) or vigorous PA (VPA). Mixed linear models were calculated, controlling for age (for TGMD-3), sex, household income, and accelerometer wear time (for accelerometry models), with childcare center as a random effect. The primary analysis reported on the cross-sectional baseline data of 126 children with complete fundamental motor skill and screen-time data; a subanalysis included 88 children with complete accelerometry data.
*Results*: Children were 3.4 ± 0.5 years of age (54% girls; 46% white, 42% African American, 12% other). A total of 48% lived in households at or below the federal poverty level. Children engaged in 5.1 ± 3.6 h/day of screen-time. Children's screen-time was inversely related to the Movement Assessment Battery for Children-2nd edition, manual dexterity skills percentile ($\beta$ (SE) = −1.7 (0.8), $p$ = 0.049). In the accelerometry subsample, children engaged in 5.9 ± 0.9 h/day of TPA of which 1.7 ± 0.6 h/day was MVPA. Boys engaged in more MVPA and VPA and less SB compared with girls (all $p < 0.05$). A higher TGMD-3, total score ($\beta$ (SE) = 0.4 (0.2), $p$ = 0.017) and locomotor score ($\beta$ (SE) = 0.7 (0.3), $p$ = 0.018) were associated with more VPA but not with TPA or MVPA. Screen-time and television in the bedroom were not related to SB, TPA, MVPA, or VPA.
*Conclusion*: Children's motor skills were positively related to VPA but inversely related to screen-time. Further inquiry into the implications of high exposure to screen-time in young children is needed.


**Keywords:** Fundamental motor skills; Physical activity; Preschool; Screen-time

## 1. Introduction

Fundamental motor skills (FMS) development is a critical aspect of early childhood. FMS are gross and fine movement patterns; gross movement patterns involve large muscle groups and FMS involve the activation of smaller muscle groups.[1] Gross motor skills are generally separated into locomotor, object control, and stability skills. Locomotor skills involve navigating the body through space with specialized movement patterns (e.g., symmetrical, asymmetrical, lateral); object control skills involve the manipulation of items either by projecting them away or receiving them; and stability skills involve the stabilization of the body's center of gravity.[1,2] Establishing competency in a wide array of FMS is essential for translation to more context-specific movement patterns that enable lifelong movement experiences.[1]

FMS have a complementary relationship with physical activity (PA) across childhood and adolescence.[3,4] The conceptual model postulated by Stodden et al.[5] centers around the reciprocal and dynamic role that FMS and PA play toward children's health. Greater competency in FMS in early childhood leads to higher levels of PA, physical fitness, and perceived motor competence in adolescence[6,7] and healthier weight.[4] Conversely, only 12% of children with low FMS competency meet PA recommendations.[8] Mastering FMS is related to higher PA levels in preschool children: preschool children who demonstrate higher FMS competence are more physically active compared with their less-skilled peers.[9−14] However, because recent guidelines for PA are changing into more comprehensive ways

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of examining all forms of movement,[15] it is important to expand on the current literature examining the relationship between FMS and total PA (TPA) to include light PA, moderate PA, and vigorous PA (VPA) as well as sedentary behavior (SB), none of which has been fully explored in this population.

PA levels are reported to be low in preschool children; in a systematic review of the literature on PA participation, Tucker[16] concluded that only 23% of preschoolers in the United States between the ages of 2 and 5 years engaged in 120 min of daily PA. Several studies have indicated that preschool children instead spend at least 80%−85% of their time in SB.[17−19] In general, preschool children engage in high amounts of SB and low amounts of PA.[18,20] Researchers have demonstrated the health benefits of PA engagement among preschool children.[21] However, SB and the influence of these sedentary activities on other health behaviors have not been thoroughly investigated in preschool populations.

A predominant way in which children accumulate SB is through screen-time. The American Academy of Pediatrics recommends that young children should spend no more than 1 h daily engaged in screen-time.[22] However, preschool children are accumulating approximately 4 h of screen-time daily.[23] Almost all preschool children (99.4%) watch television; additionally, one-third of young children play games on computers or electronic devices, and a little more than one-quarter use the Internet for other activities beyond playing games.[24] Among preschool children, it seems that PA behaviors decrease and screen-based behaviors increase as children age.[24] Cadoret et al.[25] found that preschool-age children maintained high screen-time behaviors across 3 years, and higher screen-time exposure was related to lower FMS proficiency at the age of 7. However, Cadoret et al.[25] did not examine FMS proficiency when children were younger, indicating a need to examine these relationships earlier to identify when they emerge. Investigations need to focus on the potential adverse relationship between SB (chiefly screen-time behavior) and FMS competence earlier in childhood to determine if lower FMS competency may be reinforcing more SB or vice versa, and how to potentially intervene before detriments to health are observed.

The purpose of the present study was to examine the associations among young children's FMS, screen-time, and PA levels. The following hypotheses were tested:

**Hypothesis 1.** Children with higher screen-time have lower FMS.

**Hypothesis 2.** Children with higher FMS spend more time engaged in TPA and moderate-to-vigorous PA (MVPA) and less time in SB.

**Hypothesis 3.** Children with higher screen-time spend less time engaged in TPA, MVPA, and VPA and more time in SB.

## 2. Methods

### *2.1. Participants and procedures*

This study reports on the baseline data collected for the Pause and Play project, a prospective observational study of preschool children in 10 childcare centers for the purpose of examining the influence of center policies and practices on children's PA and screen-time.[26,27] A complete list of licensed childcare centers was obtained from the Louisiana Department of Education along with an indication of whether each center received childcare assistance funding. A statistician randomly ordered the childcare centers. Research staff contacted each center at least 3 times to invite the director to participate, with contacts occurring via mailed letter, phone call, and/or email. Ultimately, 10 centers were enrolled in the larger project, and 8 of these centers participated in the assessments of FMS reported herein.

After the center director agreed in writing to participate in the project, all parents of children 3 and 4 years old attending the center were notified about the study before data collection. Information about the study purpose, procedures, and timeline was delivered to parents in at least 2 of the following ways: informational handout/flyer, phone call, email, mail, or in person. A child was eligible to participate if he or she was 3 or 4 years old, attended the childcare center full time, and planned to attend the same childcare center the following year, which allowed for a follow-up assessment. Parents provided written consent for their child to participate in the study. Owing to their young age, children were not asked to provide documented verbal assent, except during FMS assessment; but all procedures were explained in child-friendly terms and a child could refuse to participate. One childcare center did require verbal assent from the children, and this assent was documented. The protocol and all study materials were approved by the Pennington Biomedical Research Center Institutional Review Board.

### *2.2. Measures*

#### *2.2.1. Anthropometry*

Height was measured using a portable stadiometer (Seca 213; Seca GmbH & Co. KG., Hamburg, Germany), and weight was measured using a digital scale (Tanita 800S; Tanita, Tokyo, Japan). Two measurements were taken for each and averaged for analysis; if the 2 measurements differed by more than 0.5 unit, a third measurement was taken. Body mass index (BMI) percentile and z-score were calculated based on sex- and age-specific norms based on the U.S. Centers for Disease Control and Prevention Growth Charts.[28]

#### *2.2.2. FMS*

*Test of Gross Motor Development-3rd edition (TGMD-3).* The TGMD-3, is a direct observation assessment that measures performance of 13 FMS in children ages 3−10 years.[29] The TGMD-3 is a process-oriented assessment that uses both criterion and normative data to evaluate performance. These skills are partitioned into 2 subscales: locomotor and ball skills. The skills assessed in the locomotor subscale include run, gallop, 1-legged hop, skip, jump, and slide. The ball skills evaluated include 2-hand strike, 1-hand strike, catch, kick, dribble, overhand throw, and underhand throw. The TGMD-3 is a valid and reliable assessment tool for measuring gross motor skill competence.[30,31] Each skill is evaluated by examining 3−5 performance criteria. For example, the performance criteria for skipping include (1) taking a step forward followed by a hop on the same foot, (2) arms flexed and moving in opposition to legs to produce force, and (3) completing 4 continuous rhythmical alternating skips.

The TGMD-3 was conducted in small groups of 3−4 participants and lasted approximately 30 min for each group. For each skill, a trained administrator demonstrated the skill. Each participant was then given 1 practice trial, followed by 2 formal trials that were observed and scored by the administrator. If a child demonstrated correctly the performance criteria, the child was awarded a score of 1 for each trial. If the child did not demonstrate the appropriate criteria, a score of 0 was recorded for the trial. Total scores from the performance criteria over the 2 formal trials were summed to create a raw skill score. Skill scores were summed to provide a total raw score for either the locomotor or ball skills subscales, or combined to provide a total TGMD-3 raw score. The locomotor subscale raw score total had a maximum of 46 points; the ball skills subscale had a maximum of 54 points. Higher scores reflected more proficient FMS performance.

Assessments were video recorded and coded by trained research assistants who reached 98% reliability in coding sample administrations before testing. In addition, one-half of the assessments were coded by at least 2 administrators, with a 98% interrater reliability achieved for these reliability checks.

*Movement Assessment Battery for Children-2nd edition (MABC-2).* The MABC-2, is a direct observation motor ability assessment that is appropriate for children between the ages of 3 and 16 years.[32] It is a product-oriented assessment that uses normative data to describe performance based on similarly aged peers. The MABC-2 is conducted individually and takes approximately 10 min to complete. This assessment examines 8 tasks that are categorized into 3 categories: manual dexterity, balance, and aiming and catching for the age band of 3−6 years. A research assistant who was trained by an expert (EKW) in motor development conducted the assessments. Manual protocols were followed for each of the subtests and for scoring, where raw scores were translated into standard scores and percentiles based on normative population data.

### 2.2.3. Screen-time and demographics

Parents completed a written demographic and screen-time survey, reporting child's date of birth, sex, race, ethnicity, household income (in USD20,000 increments from less than USD10,000 to up to USD140,000 and above), and total number of people in the child's house. Household income categories based on the number of people in the household were compared with the federal poverty level to classify each child's household as above or at or below the federal poverty level.[33]

Parents reported each child's screen-time using questions from the National Health and Nutrition Examination Survey 2009−2010 questionnaire, which is similar to reliable and valid self-report instruments used in other studies.[34] The basic question was, "During the past 30 days, on average how many hours per day did your child sit and watch television (TV) or videos outside of school?" The answer options were none, less than 1, 1, 2, 3, 4, 5, or more than 5 h. None was coded as 0 h/day and less than 1 h was coded as 30 min/day. The basic question was repeated 4 times to query for "use a computer or play computer games", "play video games", "use a smartphone", and "use an iPad or tablet". No parents indicated more than 5 h/day for any device. Parents also reported on whether the child had a television in his or her bedroom. Parents' survey responses were entered by research staff into Research Electronic Data Capture (REDCap 8.5.18; Vanderbilt University, Nashville, TN, USA), an Health Insurance Portability and Accountability Act of 1996 (HIPAA)-compliant website tool used for research purposes.[35] Screen-time was examined separately by device and also summed to create a total amount of screen-time hours per day.

### 2.2.4. PA

Children were asked to wear accelerometers (ActiGraph GT3X+; ActiGraph LLC, Pensacola, FL, USA) attached to a nylon belt, which were placed on the right hip anterior to the iliac crest. Accelerometers were worn for 7 days, 24 h/day, and the accelerometry data collection did not overlap with the FMS assessment days. During the consent process, teachers and parents were provided with information on the proper location for accelerometer placement and the desired wear time for the project, and research staff checked for accelerometer wear during each school day. ActiLife software Version 5.6 (ActiGraph) was used to process the accelerometry data to calculate wear time and determine duration of activity. Accelerometry data were processed using 15-s epochs, and valid wear time was considered to be at least 10 h of wear time for at least 3 days. Nonwear time was established by 30 min of continuous 0 count per minute (cpm).[36] Established cut points were used to classify SB and TPA (light PA, moderate PA, and VPA) and VPA based on the criteria of Pate et al.:[15] sedentary: 0−799 cpm; light: 800−1679 cpm; moderate: 1680−3367 cpm; and vigorous: 3368 cpm or more. MVPA was classified as 1680 cpm or more.

## 2.3. Statistical analysis

A total of 126 children completed the FMS assessments and were included in the main analyses (Hypothesis 1). Of these participants, 88 children had complete accelerometry data and were included in the accelerometry analyses (Hypotheses 2 and 3). Children in the accelerometry subgroup did not differ from children in the full sample by age, sex, BMI z-score, race, federal poverty level (an indicator of socioeconomic status), screen-time, or total TGMD-3 or MABC-2 score. A total of 9 parent-reported total screen-time values were censored for being more than 2 standard deviations above the median. We used $t$ tests and $\chi^2$ tests to examine differences in primary variables by sex, $\alpha$ levels were set at $< 0.05$ a priori.

Mixed linear models were calculated using PROC MIXED in SAS software Version 9.4 (SAS Institute Inc., Cary, NC, USA), controlling for the random effect of childcare center to take into account the clustering of children. Bivariate correlations indicated significant associations among MVPA, SB, or FMS with age, sex, and household income, which were included as covariates in all analyses. Accelerometer wear-time was included in the accelerometry analyses. Age was not included for the MABC-2 models because these scores are adjusted for age. BMI z-score was not related to MVPA, SB, or FMS (Pearson's $r < 0.15$) and was not included as a covariate. Interactions were tested between sex and the primary independent variables of interest, but were not significant and, therefore, were not included in the models.

To test Hypothesis 1, mixed models were used to examine the association of total screen-time as the independent variable and each FMS score as the dependent variable. For the TGMD-3, total raw scores as well as locomotor and object control skills were used. For the MABC-2, total percentile scores were used, along with percentile scores for manual dexterity, balance, and aiming and catching subscales. These models were repeated with TV in the bedroom as the independent variable.

To test Hypothesis 2, mixed models were used to examine FMS as the independent variable with each activity category (SB, TPA, MVPA, or VPA) as the dependent variable.

To test Hypothesis 3, mixed models were used to examine total screen-time as the independent variable with each activity category (SB, TPA, MVPA, or VPA) as the dependent variable. These models were repeated with TV in the bedroom as the independent variable.

## 3. Results

### 3.1. Participant characteristics

Children were 3.4 ± 0.5 years of age. Table 1 presents demographic characteristics for the overall sample by sex. Based on total screen-time summed across 5 devices, children engaged in 5.1 ± 3.6 h/day of screen-time. Compared with girls, boys had better TGMD-3 total scores ($p < 0.01$), ball skills ($p < 0.001$), and MABC-2 aiming and catching percentile scores ($p < 0.05$); girls had higher MABC-2 manual dexterity scores ($p < 0.05$) and manual dexterity percentile scores ($p < 0.05$). There were no sex differences in screen-time.

In the accelerometry subsample, children engaged in 5.9 ± 0.9 h/day of TPA, of which 1.7 ± 0.6 h/day was MVPA. Of the 88 children in the subsample, 57 had at least 1 complete weekend day included in their accelerometry data; TPA, MVPA, and VPA did not differ between those who did have a weekend day *vs.* those who did not. Compared with girls, boys engaged in significantly more TPA ($p < 0.01$), MVPA ($p < 0.001$), MPA ($p < 0.001$), and VPA ($p < 0.001$) and significantly less SB ($p < 0.05$).

Table 1
Participant baseline characteristics.

| | Boys ($n = 58$) | Girls ($n = 68$) | All ($n = 126$) |
|---|---|---|---|
| **Age (year)** | 3.4 ± 0.5 | 3.3 ± 0.5 | 3.4 ± 0.5 |
| **Race (%)** | | | |
| White | 48 | 44 | 46 |
| Black | 34 | 49 | 42 |
| Asian | 10 | 6 | 8 |
| Not reported | 7 | 1 | 4 |
| **Ethnicity (%)** | | | |
| Hispanic | 7 | 2 | 4 |
| Non-Hispanic | 93 | 98 | 96 |
| **Below federal poverty level** | 49 | 47 | 48 |
| **BMI z-score** | 0.2 ± 1.0 | 0.3 ± 1.2 | 0.3 ± 1.2 |
| **BMI (%)** | | | |
| Underweight | 6 | 5 | 6 |
| Healthy weight | 68 | 72 | 70 |
| Overweight | 13 | 19 | 16 |
| Obese | 13 | 3 | 9 |
| **Screen-time (h/day)**[a] | 5.1 ± 3.5 | 5.1 ± 3.8 | 5.1 ± 3.6 |
| TV | 1.9 ± 1.3 | 1.9 ± 1.1 | 1.9 ± 1.2 |
| Computer | 1.0 ± 1.3 | 0.6 ± 1.0 | 0.8 ± 1.2 |
| Video games | 0.6 ± 1.0 | 0.6 ± 1.0 | 0.6 ± 1.0 |
| Smartphone | 0.8 ± 1.0 | 0.8 ± 1.3 | 0.9 ± 1.1 |
| Tablet | 1.1 ± 1.2 | 1.1 ± 1.2 | 1.2 ± 1.2 |
| **TV in child's bedroom** | 43 | 40 | 41 |
| **TGMD-3** | 40.6 ± 12.3** | 35.2 ± 10.7 | 37.7 ± 11.7 |
| Percentile | 46.3 ± 25.2 | 44.2 ± 20.8 | 45.2 ± 22.9 |
| *Locomotor skills* | 16.6 ± 6.5 | 16.9 ± 6.7 | 16.8 ± 6.6 |
| Percentile | 36.9 ± 24.4 | 38.1 ± 23.3 | 37.5 ± 23.7 |
| *Ball skills* | 24.0 ± 7.5*** | 18.3 ± 6.3 | 20.9 ± 7.4 |
| Percentile | 57.5 ± 25.1 | 53.6 ± 22.8 | 55.5 ± 23.9 |
| **MABC-2** | 8.0 ± 2.6 | 8.3 ± 3.0 | 8.2 ± 2.8 |
| Percentile | 30.8 ± 23.4 | 32.3 ± 27.2 | 31.6 ± 25.4 |
| *Manual dexterity* | 6.9 ± 2.4 | 8.0 ± 3.1* | 7.5 ± 2.8 |
| Percentile | 20.9 ± 20.2 | 30.8 ± 28.0* | 26.3 ± 25.1 |
| *Aiming and catching* | 10.7 ± 3.3 | 9.7 ± 2.7 | 10.1 ± 3.1 |
| Percentile | 57.3 ± 29.5* | 47.1 ± 27.1 | 51.8 ± 28.6 |
| *Balance* | 8.7 ± 3.2 | 9.0 ± 3.2 | 8.8 ± 3.2 |
| Percentile | 34.9 ± 28.7 | 38.0 ± 28.6 | 36.5 ± 28.6 |
| **Activity (h/day)**[a] | | | |
| *Sedentary behavior* | 6.0 ± 0.8 | 6.4 ± 0.8* | 6.2 ± 0.9 |
| *TPA* | 6.2 ± 1.0** | 5.6 ± 0.8 | 5.9 ± 0.9 |
| LPA | 4.2 ± 0.6 | 4.1 ± 0.5 | 4.1 ± 0.5 |
| MPA | 1.3 ± 0.4*** | 1.1 ± 0.3 | 1.2 ± 0.3 |
| VPA | 0.6 ± 0.3*** | 0.4 ± 0.2 | 0.5 ± 0.3 |
| MVPA | 2.0 ± 0.6*** | 1.5 ± 0.5 | 1.7 ± 0.6 |

Note: Values are mean ± standard deviation or proportion (may not equal 100 due to rounding).
[a] $n = 88$ (41 boys, 47 girls) owing to incomplete accelerometry data.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, compared between sex.
Abbreviations: BMI = body mass index; LPA = light physical activity; MABC-2 = Movement Assessment Battery for Children-2nd edition; MPA = moderate physical activity; MVPA = moderate-to-vigorous physical activity; PA = physical activity; TGMD-3 = Test of Gross Motor Development-3rd edition; TV = television; VPA = vigorous physical activity; TPA = total physical activity.

### 3.2. Screen-time and FMS

Hypothesis 1 was partially supported. Children's total screen-time was inversely related to MABC-2 manual dexterity skills percentile ($\beta$ (SE) = −1.7 (0.8), $p = 0.049$). Associations were observed between children's screen-time and MABC-2 total percentile but did not reach significance ($\beta$ (SE) = −1.6 (0.9), $p = 0.07$). There was no association between screen-time and MABC-2 balance or aiming and catching subscales. Child's screen-time was not significantly related to TGMD-3 total score or subscales (locomotor skills, ball skills). TV in the bedroom was not related to MABC-2 or TGMD-3 scores. Sex was a significant covariate in the models, with boys having higher TGMD-3 total scores and TGMD-3 ball skills and girls having higher MABC-2 manual dexterity skills ($p < 0.05$).

### 3.3. FMS and amount of activity

Hypothesis 2 was partially supported (Table 2). A higher TGMD-3 total score ($\beta$ (SE) = 0.4 (0.2), $p = 0.017$) and locomotor score ($\beta$ (SE) = 0.7 (0.3), $p = 0.018$) were associated with more minutes per day of VPA. Positive associations between MVPA and TGMD-3 total score ($\beta$ (SE) = 0.6 (0.3), $p = 0.053$) and between MVPA and TGMD-3 locomotor skills ($\beta$ (SE) = 0.9 (0.5), $p = 0.091$) did not meet the significance threshold. There were no significant associations between

TGMD-3 and SB or TPA. In each model, sex was significant, indicating that boys engaged in more TPA, MVPA, and VPA and less SB compared with girls ($p < 0.05$).

The children's MABC-2 total score percentile was not significantly related to the amount of SB, TPA, MVPA, or VPA. Associations did not reach significance between MABC-2 aiming and catching percentile and MVPA ($\beta$ (SE) = 0.2 (0.1), $p$ = 0.097) and VPA ($\beta$ (SE) = 0.1 (0.1), $p$ = 0.090). In each model, sex was a significant covariate, indicating that boys engaged in more TPA, MVPA, and VPA but less SB compared with girls ($p < 0.05$).

### 3.4. Screen-time and amount of activity

Hypothesis 3 was not supported. There were no associations between screen-time and SB, TPA, MVPA, or VPA. Having a TV in the bedroom was not related to SB, TPA, MVPA, or VPA. Sex was a significant covariate, indicating that boys engaged in more TPA, MVPA, and VPA and less SB compared with girls ($p < 0.05$).

## 4. Discussion

In light of the importance of FMS in early childhood, this study investigated the relationships among young children's PA, SB, and screen-time, with FMS competency. Mixed results were found in relation to our hypotheses. Screen-time was inversely associated with FMS; however, this relationship was only statistically significant in relation to manual dexterity. PA and SB were not associated with screen-time, which was counterintuitive to the notion that more screen-time would elicit less PA and more SB.

### 4.1. Screen-time and FMS

The evidence indicated that higher amounts of screen-time were inversely related to FMS competence. Specifically, children who engaged in more screen-time performed worse on the MABC-2 manual dexterity subscale. Manual dexterity is a critical skill for children to develop and is associated with fine motor patterns used for activities such as drawing or writing,[1] as well as academic achievement.[37] In the present study, children, on average, were engaging in screen-time totaling more than 5 times the recommended amount,[22] and these excessive levels of screen-time were associated with poorer manual dexterity skills. Although boys and girls engaged in similar amounts of screen-time, boys scored worse on manual dexterity skills and, therefore, may be particularly susceptible in this FMS domain. Previous work, as well as the present study, has considered the likely impact of the ubiquitous place of screens in today's society and how these screens may negatively influence FMS competence in children. Gaul and Issartel[38] suggest that fine motor skills improve with age; however, when compared with normative values, children's performance is worsening over time. In the present study, detrimental relationships between screen-time and manual dexterity were observed in children as young as 3 years; longitudinal research is needed to examine if many years of excessive screen-time contributes to worse fine motor skills development over the long term.

Table 2
Mixed models examining the association of children's scores on the TGMD-3 with MVPA and VPA.

| | MVPA (min/day) | | VPA (min/day) | |
|---|---|---|---|---|
| | $\beta$ (SE) | $p$ | $\beta$ (SE) | $p$ |
| TGMD-3 total score | 0.6 (0.3) | 0.053 | 0.4 (0.2) | 0.017 |
| Boys *vs.* girls | 18.0 (6.5) | 0.007 | 8.4 (3.3) | 0.012 |
| TGMD-3 locomotor skills score | 0.9 (0.5) | 0.091 | 0.7 (0.3) | 0.018 |
| Boys *vs.* girls | 22.3 (6.4) | <0.001 | 11.2 (3.2) | <0.001 |
| TGMD-3 ball skills score | 0.6 (0.5) | 0.208 | 0.4 (0.3) | 0.133 |
| Boys *vs.* girls | 22.1 (6.9) | 0.002 | 7.8 (3.6) | 0.036 |

Note: Mixed models controlled for age, accelerometer wear time, household income, and clustering of children within childcare center.
Abbreviations: MVPA = moderate-to-vigorous physical activity; TGMD-3 = Test of Gross Motor Development-3rd edition; VPA = vigorous physical activity.

Interestingly, screen-time behaviors were not related to overall FMS among these preschool-aged children. The ages of 3–4 years may be too early to observe potential detrimental associations of prolonged exposure to screens and screen-based activities with FMS competency, and there is sparse research on the impact of screen-time and FMS competence in this age range. Cadoret et al.[25] examined longitudinal screen-time behaviors and FMS proficiency, observing that children who engaged in more screen-time at ages 4 and 5 had lower proficiency in FMS at age 7 years. By contrast, mixed results have been observed for short-term effects during the preschool years. For example, 1 observational study indicated that preschoolers who had more frequent computer use demonstrated poorer locomotor skills and poorer overall FMS performance.[39] In children younger than 3 years of age, researchers found that increased television viewing was associated with motor, cognitive, and language delays.[40] However, children with higher object control skill competency were found to play more interactive video games compared with their less skilled peers.[41] It is probable that certain types of screen activities, like sedentary television viewing or computer usage, might have a more detrimental impact on FMS competence compared with all forms of screen-time examined in the present study, including tablets, smartphones, and video games. Future work is needed to determine if there are screen-based activities that might actually promote FMS competency or that have no effect on FMS competency in preschool children, as well as the directionality of this relationship for each screen platform.

### 4.2. FMS and amount of activity

The present study observed that preschool children with higher FMS competency were more likely to engage in higher amounts of VPA and, to a lesser extent, MVPA. This finding is in accordance with previous work that has shown preschoolers with higher FMS competence tend to engage in greater amounts of PA.[9,11,12,42] Girls were shown to be at a deficit compared with boys in regards to both PA and FMS: consistently across the models, girls engaged in less MVPA and VPA and had lower scores on the TGMD-3 and the aiming and catching component of the MABC-2. A recent systematic review found that all studies involving preschool-age children that were reviewed observed a positive relationship between FMS and PA behavior, with the strength of the bivariate relationships ranging from low to moderate.[3] Furthermore, relationships between FMS and engagement in PA strengthened over childhood, providing evidence in support of the Dynamic Association Model[5] in which FMS and PA play a dynamic and reciprocal role in promoting healthy development in children.

Indeed, the present data support the growing consensus in the literature that motor competence has a positive relationship with PA and plays a central role in promoting children's health.[4] In the cross-sectional analysis presented herein, children with higher FMS competence also engaged in the greatest amounts of VPA, indicating that children with more proficient movement patterns tended to move more and at greater intensities. This relationship highlights the continued need to encourage VPA for FMS development in preschool-age children, because research has shown that these motor skills do not emerge naturally but must be taught and practiced.[43] Opportunities to promote PA among children exist at childcare centers.[44] Prior examination of Pause and Play data indicated that children spent one-half of their time during an observed classroom day engaged in TPA, including 15% of the total time engaged in MVPA.[27] Future research should examine opportunities within the classroom for engagement specifically in VPA to promote FMS development.

Interestingly, there were differences in the relationship between PA and FMS based on the assessment tool used. Total TGMD-3 score and the locomotor subscale were associated with VPA engagement. This finding is not surprising, because children are more likely to first develop locomotor skills before learning and refining object control activities.[2] By contrast, there were no significant associations observed between PA and FMS assessed by the MABC-2.

Differences between the relationships shown between PA behaviors and FMS competence may be related to the orientation of the assessment tool. The TGMD-3 is a process-oriented assessment that examines the execution of the movement patterns children engage in during various locomotor and object control tasks.[30] Using another process-oriented assessment, Williams et al.[13] found that preschool children with the highest FMS competency participated in more MVPA and VPA time. Additionally, children with the highest locomotor skill scores participated in significantly less SB,[13] which was not replicated in the present study. Process-oriented movement patterns reflect the most mature movement forms; children who perform skills correctly may be more likely to engage in PA opportunities that require the use of these FMS.

The MABC-2, by contrast, is a product-oriented assessment that examines the resultant behavior of several FMS tasks, specifically manual dexterity, balance, and aiming and catching. The end result of these movement patterns, in theory, would be that the child becomes quicker and more efficient as he or she gains more control over the coordination of certain movement patterns that the MABC-2 examines, such as stringing beads or balancing on 1 foot. In the present study, no significant relationships were identified between PA and the MABC-2. DuBose et al.[45] found in a sample of children between 3 and 10 years old that higher levels of MPA and MVPA were related to higher MABC-2 scores. The observed association with aiming and catching with VPA found in our sample may be because the children observed in our study accumulated twice as much VPA compared with the children in the DuBose et al.[45] study (average of 0.60 h compared with 0.35 h, respectively). These results highlight the need to take a multifaceted approach to understanding FMS in preschool children and to incorporate both process- and product-oriented assessments to better understand the nuances of the relationship between FMS and PA.

### 4.3. *Screen-time and amount of activity*

Higher amounts of screen-time might deter children from the opportunity to engage in PA experiences; however, in the present study no relationship was observed between the amount of screen-time in which children engaged and any intensity or amount of PA. These findings align with a recent systematic review in which the presence of screens in the home was not related to PA behaviors; although screens in the home were positively related to SB in two-thirds of the studies reviewed.[46] Furthermore, similar to the present findings, a second systematic review observed no consistent evidence between preschool children's screen-time behavior (i.e., TV viewing) and PA engagement.[47]

The location, context, and type of screen-time activity may change the association between screen-time and PA, particularly based on whether screen-time displaces physically active play. For instance, a prior examination of the children in Pause and Play indicated that the childcare centers' screen reduction policies and practices were related to higher PA and less SB while the children were attending the center.[27] This direct, inverse association between screen-time and PA may be because screen-time in childcare centers is currently used as a sedentary indoor pastime,[27] whereas children's screen-time outside of childcare has diversified to include physically active screen-time, outdoor screen-time, mobile screen-time in the car when the child is not typically physically active, and engagement with a variety of mobile devices, including video games, tablets, and smartphones.

Future research should examine specific devices, the content and programs viewed on these devices, whether or not a parent or caregiver interacted with the child during screen-time, and if these media devices involve a PA component. Furthermore, careful investigation is needed to determine the location and context of health-promoting screen-time behaviors and, if children are going to continue to engage in excessive screen-based behaviors, how healthy behaviors such as FMS development or PA can be incorporated to create healthy screen-time experiences.

Finally, associations between screen-time and adverse health behaviors and health outcomes detected at later years in childhood may not yet be observed during the preschool years. For example, in an older and international sample of children, MVPA and VPA were inversely related to obesity, and TV viewing was positively associated with obesity.[48] Over time, it is likely that more total accumulated time spent toward sedentary screen-time may naturally deter opportunities for PA and contribute to excessive weight gain; but these associations have not been observed consistently in the preschool years.

### *4.4. Limitations*

The current study has several limitations that should be addressed. First, the data were cross-sectional, so no causality conclusions may be drawn. This is an initial investigation into the interrelationship of these screen-time and PA behaviors with FMS, but longitudinal work and experimental designs are essential for examining directionality and causality. Future research should examine these relationships over several years to better identify how screen-time, PA, and FMS development change across the lifespan. Second, the sample is small but includes a diverse sampling of children across household income, including a high proportion of families from underserved households and a high proportion of African American children. Future work needs to be extended to larger groups, other racial/ethnic minority groups, and different regions of the country to examine sociocultural and socioeconomic influences on children's PA and screen-time behaviors and to increase the overall generalizability of the results. Finally, the Pate et al.[15] cut points used to classify PA levels were selected because they have been validated against indirect calorimetry in preschool children. However, it is recognized that the use of different cut points and epoch lengths result in inconsistencies in PA estimates in preschoolers; therefore, the present results may not be comparable with studies using different standards.

## 5. Conclusion and practical implications

Based on the evidence review and resulting recommendations from the American Academy of Pediatrics,[22] previous literature has indicated that an adverse relationship exists between large amounts of screen-based behaviors and young children's cognitive/developmental delay, unhealthy weight, and poor sleep. At this time, the directionality of excess screen exposure, PA, and FMS has not been well-explored. The present study observed an adverse association of screen-time with manual dexterity skills but not for other FMS or PA; although it is possible that more screen-time over a longer period of time may contribute to gradual detriments in PA participation and FMS development that are detected later in childhood. There is also the underlying question: Is all screen-time bad for children's development? There is ample opportunity to use screen-based devices, based on current use rates, to target health-related behaviors such as building FMS competency and increasing PA for young children as a strategy that may improve long-term health. Identifying ways for young children to use these screen devices without impairing important fundamental skills and without displacing PA remains a priority.

There are several practical implications that have derived from this study that warrant further investigation. First, sex differences were present in PA, SB, and FMS in preschool-age children, favoring more positive healthy trajectories for boys. This finding underlies an important time during childhood to target interventions that may minimize these health-related gaps specifically by improving FMS, PA, and SB for girls, as well as focusing on fine motor skill development for boys. Second, screen-time was well above the recommendations for this age group. Early in preschool, it seems that PA was not negatively impacted; however, components of FMS proficiency were inversely related with greater amounts of screen-time. At the same time, higher FMS proficiency was related to more VPA. Longitudinal work is needed to determine whether excessive screen-time continues to impact FMS competence and whether it indirectly impacts children's PA through lower levels of FMS. The preschool years are an ideal time to target health-related behaviors, particularly at childcare centers, a location that previously been shown to impact all 3 health behaviors investigated in this study. Additionally, because screen-time is likely to be a home-based activity, it is critical that future work focus on the home environment to increase PA and FMS proficiency and reduce excessive amounts of screen-time and SB among young children.


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## Authors' contributions

EKW and AES conceived of the study, designed and coordinated the study, performed statistical analysis and interpretation, and wrote the initial draft of the manuscript; CKM provided scientific guidance for the design and coordination of the study and interpretation of results. All authors provided critical feedback to the manuscript, have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

## Competing interests

The authors declare that they have no competing interests.

## References


1. Clark JE, Metcalf JS. The mountain of motor development: a metaphor. In: Clark JE, Humphrey JH, editors. *Motor development: research and*

*reviews*. Vol. 2. Reston, VA: National Association for Sport and Physical Education; 2002.p.163–90.
2. Haywood K, Getchell N. *Lifespan motor development*. 6th ed. Chicago, IL: Human Kinetics; 2014.
3. Logan SW, Webster EK, Getchell N, Pfeiffer KA, Robinson LE. Relationship between fundamental motor skill competence and physical activity during childhood and adolescence: a systematic review. *Kinesiol Rev* 2015;**4**:416–26.
4. Robinson LE, Stodden DF, Barnett LM, Lopes VP, Logan SW, Rodrigues LP, et al. Motor competence and its effect on positive developmental trajectories of health. *Sports Med* 2015;**45**:1273–84.
5. Stodden DF, Goodway JD, Langendorfer SJ, Roberton MA, Rudisill ME, Garcia C, et al. A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. *Quest* 2008;**60**:290–306.
6. Barnett LM, Van Beurden E, Morgan PJ, Brooks LO, Beard JR. Childhood motor skill proficiency as a predictor of adolescent physical activity. *J Adolesc Health* 2009;**44**:252–9.
7. Barnett L, Van Beurden E, Morgan P, Brooks L, Beard J. Does childhood motor skill proficiency predict adolescent fitness. *Med Sci Sports Exerc* 2008;**40**:2137–44.
8. De Meester A, Stodden D, Goodway J, True L, Brian A, Ferkel R, et al. Identifying a motor proficiency barrier for meeting physical activity guidelines in children. *J Sci Med Sport* 2018;**21**:58–62.
9. Cliff DP, Okely AD, Smith LM, McKeen K. Relationships between fundamental movement skills and objectively measured physical activity in preschool children. *Pediatr Exerc Sci* 2009;**21**:436–49.
10. Fisher A, Reilly JJ, Kelly LA, Montgomery C, Williamson A, Paton JY, et al. Fundamental movement skills and habitual physical activity in young children. *Med Sci Sports Exerc* 2005;**37**:684–8.
11. Robinson LE, Goodway JD. Instructional climates in preschool children who are at-risk. Part I: object-control skill development. *Res Q Exerc Sport* 2009;**80**:533–42.
12. Robinson LE, Wadsworth DD, Peoples CM. Correlates of school-day physical activity in preschool students. *Res Q Exerc Sport* 2012;**83**:20–6.
13. Williams HG, Pfeiffer KA, O'Neill JR, Dowda M, McIver KL, Brown WH, et al. Motor skill performance and physical activity in preschool children. *Obesity* 2008;**16**:1421–6.
14. Sääkslahti A, Numminen P, Niinikoski H, Rask-Nissila L, Viikari J, Tuominen J, et al. Is physical activity related to body size, fundamental motor skills, and CHD risk factors in early childhood? *Pediatr Exerc Sci* 1999;**11**:327–40.
15. Pate RR, Almeida MJ, McIver KL, Pfeiffer KA, Dowda M. Validation and calibration of an accelerometer in preschool children. *Obesity* 2006; **14**:2000–6.
16. Tucker P. The physical activity levels of preschool-aged children: a systematic review. *Early Child Res Q* 2008;**23**:547–58.
17. Cardon GM, De Bourdeaudhuij IM. Are preschool children active enough? Objectively measured physical activity levels. *Res Q Exerc Sport* 2008;**79**:326–32.
18. Pate RR, McIver K, Dowda M, Brown WH, Addy C. Directly observed physical activity levels in preschool children. *J Sch Health* 2008;**78**:438–44.
19. Sugiyama T, Okely AD, Masters JM, Moore GT. Attributes of child care centers and outdoor play areas associated with preschoolers' physical activity and sedentary behavior. *Environ Behav* 2012;**44**:334–49.
20. Hnatiuk JA, Salmon J, Hinkley T, Okely AD, Trost S. A review of preschool children's physical activity and sedentary time using objective measures. *Am J Prev Med* 2014;**47**:487–97.
21. Vazou S, Mantis C, Luze G, Krogh JS. Self-perceptions and social−emotional classroom engagement following structured physical activity among preschoolers: a feasibility study. *J Sport Health Sci* 2017;**6**:241–7.
22. Council on Communications and Media. Media and young minds. *Pediatrics* 2016;**138**: e20162591. doi:10.1542/peds.2016-2591.
23. Tandon PS, Zhou C, Lozano P, Christakis DA. Preschoolers' total daily screen time at home and by type of child care. *J Pediatr* 2011;**158**:297–300.
24. Hinkley T, Salmon J, Okely AD, Crawford D, Hesketh K. Preschoolers' physical activity, screen time, and compliance with recommendations. *Med Sci Sports Exerc* 2012;**44**:458–65.
25. Cadoret G, Bigras N, Lemay L, Lehrer J, Lemire J. Relationship between screen-time and motor proficiency in children: a longitudinal study. *Early Child Dev Care* 2018;**188**:231–9.
26. Staiano AE, Allen AT, Fowler W, Gustat J, Kepper MM, Lewis L, et al. State licensing regulations on screen time in childcare centers: an impetus for participatory action research. *Prog Community Health Partnersh* 2018;**12**:101–9.
27. Staiano AE, Webster EK, Allen AT, Jarrell AR, Martin CK. Screen time policies and practices in early care and education centers in relation to child physical activity. *Child Obes* 2018;**14**:341–8.
28. Centers for Disease Control and Prevention. *A SAS program for the CDC growth charts*. Available at: http://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm; 2011. [accessed 07.09.2015].
29. Ulrich DA. *Test of gross motor development*. 3rd ed. Austin, TX: Pro-ed, Inc.; 2019.
30. Ulrich DA. The Test of Gross Motor Development-3 (TGMD-3): administration, scoring, & international norms. *Spor Bilimleri Dergisi* 2013;**24**:27–33.
31. Webster EK, Ulrich DA. Evaluation of the psychometric properties of the Test of Gross Motor Development-3rd edition. *J Mot Learn Dev* 2017;1–25.
32. Henderson SE, Sugden DA, Barnett AL. *Movement assessment battery for children-2*. London: Harcourt Assessment; 2007.
33. Burwell SM. Annual update of the HHS poverty guidelines. *Fed Reg* 2016;**81**:4036–7.
34. Clark BK, Sugiyama T, Healy GN, Salmon J, Dunstan DW, Owen N. Validity and reliability of measures of television viewing time and other non-occupational sedentary behaviour of adults: a review. *Obes Rev* 2009;**10**:7–16.
35. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap): a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;**42**:377–81.
36. Sisson SB, Li J, Stoner J, Lora KR, Campbell JE, Arnold SH, et al. Tribally-affiliated childcare center environment and obesogenic behaviors in young children. *Prev Med Rep* 2017;**117**:433–40.
37. Cameron CE, Brock LL, Murrah WM, Bell LH, Worzalla SL, Grissmer D, et al. Fine motor skills and executive function both contribute to kindergarten achievement. *Child Dev* 2012;**83**:1229–44.
38. Gaul D, Issartel J. Fine motor skill proficiency in typically developing children: on or off the maturation track? *Hum Mov Sci* 2016;**46**:78–85.
39. Li X, Atkins MS. Early childhood computer experience and cognitive and motor development. *Pediatrics* 2004;**113**:1715–22.
40. Lin LY, Cherng RJ, Chen YJ, Chen YJ, Yang HM. Effects of television exposure on developmental skills among young children. *Infant Behav Dev* 2015;**38**:20–6.
41. Barnett LM, Hinkley T, Okely AD, Hesketh K, Salmon J. Use of electronic games by young children and fundamental movement skills? *Percept Mot Skills* 2012;**114**:1023–34.
42. Iivonen KS, Saakslahti AK, Mehtala A, Villberg JJ, Tammelin TH, Kulmala JS, et al. Relationship between fundamental motor skills and physical activity in 4-year-old preschool children. *Percept Mot Skills* 2013;**117**:627–46.
43. Logan SW, Robinson LE, Wilson AE, Lucas WA. Getting the fundamentals of movement: a meta-analysis of the effectiveness of motor skill interventions in children. *Child Care Health Dev* 2012;**38**:305–15.
44. Webster EK, Wadsworth DD, Lobinson LE. Preschoolers' time on-task and physical activity during a classroom activity break. *Pediatr Exerc Sci* 2015;**27**:160–7.
45. DuBose KD, Gross McMillan A, Wood AP, Sisson SB. Joint relationship between physical activity, weight status, and motor skills in children aged 3 to 10 years. *Percept Mot Skills* 2018;**125**:478–92.
46. Maitland C, Stratton G, Foster S, Braham R, Rosenberg M. A place for play? The influence of the home physical environment on children's physical activity and sedentary behaviour. *Int J Behav Nutr Phys Act* 2013;**10**:99. doi:10.1186/1479-5868-10-99.
47. Bingham DD, Costa S, Hinkley T, Shire KA, Clemes SA, Barber SE. Physical activity during the early years: a systematic review of correlates and determinants. *Am J Prev Med* 2016;**51**:384–402.
48. Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, et al. Relationship between lifestyle behaviors and obesity in children ages 9-11: results from a 12-country study. *Obesity* 2015;**23**:1696–702.