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Association between parental stress, coping, mood, and subsequent child physical activity and screen-time: an ecological momentary assessment study

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Abstract

Background Few children meet physical activity and screen-time guidelines. Parents play a key role in supporting children's physical activity and limiting child screen-time, but their own stress, management of stress (i.e., coping), and mood may impact their ability to do so. Ecological momentary assessment (EMA) is a methodology that can be used to assess the temporality of parental state (i.e., stress, mood) and subsequent child behavior. This study aimed to examine the relationship between parental stress, coping, and mood with child physical activity and screen-time, and whether there were differences by child sex.

Methods Parents and their children ($n = 436$, 5–9 y) participated in an EMA study that used signal-contingent and end-of-day surveys. Parents received three signal-contingent surveys during fixed 3-hour windows and one end-of-day survey over 7-days via smartphone notifications. Parents reported their current stress, ability to manage stress, and depressive mood at the first signal-contingent survey. Parents also reported the frequency of their child's physical activity and screen-time across the day during the end-of-day survey. Conditional fixed effects regression was fitted to examine current and lagged day stress, coping, and mood relationships on change in child physical activity and screen-time.

Results Children were girls (53.7%), mainly non-white (64.3%), and with a household income of less than \$50,000 USD (54.1%). Overall, parent's current day stress was negatively related to the frequency of child physical activity ($p = 0.001$), but not screen-time. Among girls, higher parent current-day stress and lower coping were related to less frequent girl's physical activity ($ps < 0.05$). Parent's lagged day stress was then associated with more frequent girl physical activity the next day ($p = 0.018$). There were no associations among parent mood or in models with only boys.

Conclusions This study found parent's stress may negatively impact child's physical activity that day, but may positively impact physical activity the next day, namely girls. Findings suggest that reducing parental stress and improving coping abilities may improve girl's physical activity, but other approaches are needed to reduce child screen-time at this age.

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Keywords Ecological momentary assessment, Stress, Physical activity, Screen-time, Children

Introduction

Physical activity during childhood is vital for physical, social, and cognitive development [1–3]. Unfortunately, children's physical activity begins to decline starting at seven years of age, and time spent in sedentary activities increases [4]. These sedentary activities may include sedentary screen-time, as only one-third of children (ages 5–12) meet current screen-time guidelines (≤ 2 h/day of recreational screen-time) [5, 6]. Based on the socioecological model of influence, the home environment and parents are important facilitators of child physical activity, especially for younger children (< 8 years) [7, 8]. A key factor that might impact child physical activity is parental stress and stress-related psychological factors. Observational evidence demonstrates that when parents experience high levels of stress, they are less active [9], and they exhibit fewer positive physical activity parenting practices (e.g., promoting children's physical activity) [10]. As a result, these fewer practices may lead to less child physical activity and potentially more screen-time, especially in girls [11], who report lower adherence to guidelines for physical activity, screen-time, and sleep relative to boys [12]. Innovative approaches to reduce parental stress and promote physical activity may result in short and long-term health benefits for parents and children.

Current literature has predominately focused on cross-sectional associations between parental stress and child physical activity, which limits understanding of the timing of stress to health behavior and designing appropriate interventions [10, 13]. Ecological momentary assessment (EMA) is a research methodology that involves repeated data collection and captures real-time data in participants' natural environments across time and context. EMA can improve upon current cross-sectional evidence which primarily assesses mental traits by examining general stress levels and mental state (e.g., one-time questionnaires) to child physical activity and sedentary time [14]. These momentary methods provide a more comprehensive and nuanced understanding to examine the temporally ordered relationship between parental stress state and child physical activity and sedentary time (e.g., sedentary screen-time). Indeed, EMA studies can examine the antecedent, behavior, and consequence pathway by sampling multiple times across the day, and across multiple days. These data can help expand upon past research that focuses on between-person differences to now understand within-person differences [s14], which may be important for improving mental states. Past EMA studies investigating parental stress have focused on their subsequent impact on parenting practices [15, 16], or children's stress with their own physical activity [17, 18]. These prior studies together reported that in children aged 8–12 years, the mother's momentary stress was related to less physical activity promoting parenting practices [15] and that children's stress was related to less subsequent physical activity [17, 18]. It may thus be posited that in momentary associations, higher levels of parental stress are related to less child engagement in physical activity. These associations may be dependent on child sex, and more important for girl's physical activity [11].

Despite the growing body of research on the relationship between parental stress and child physical activity and screen-time, there is limited research examining the lagged effects of parental stress on child physical activity and screen-time. Consideration of parental stress within a certain day omits the consideration of previous stress influencing next-day behaviors, and states [19]. Further, other aspects of parent stress, including the ability to cope with stress and their own mood may provide context for both protective and hindering factors, respectively, to experiencing stress [20, 21]. For example, one EMA study of 191 mother-child dyads found that the mother's momentary ability to cope with stress was related to their own and their child's sweets and salty foods intake later in the day [20]. These findings suggest that the mother's ability to cope may play a role in supporting children's health behaviors. Finally, EMA has a strong relationship with device-measured child physical activity and sedentary time [22], but sedentary time may also reference other activities such as reading or homework. Examining screen-time, rather than sedentary time, may provide more detailed information on a child's actual sedentary behavior. Findings from this study can provide evidence to support actionable daily targets to manage parental stress to support a child's engagement in physical activity and reduce screen-time for informing intervention development.

This study examined the association between parents' self-reported momentary stress on children's physical activity and screen-time. A secondary aim was to examine the association between parent's momentary coping and mood on children's physical activity and screen-time. In addition, we explored potential differences by child sex in the associations examined in both aims. We hypothesized that parent stress will negatively impact child physical activity and screen-time, particularly in girls.

Methods

Participants

Family Matters is an incremental, 2-phased, mixed-methods study conducted with a racially and ethnically diverse population from mainly low-income households. The purpose of the *Family Matters* study is to examine barriers and facilitators of child cardiovascular health within the home environment [16, 23]. The first phase was an in-depth, mixed-method cross-sectional study of 150 families (25 of African American, Native American, Somali, Latino, Hmong, and White). To identify risk and protective factors for childhood obesity, a longitudinal cohort study was conducted for Phase II. The first phase informed procedures/protocols (e.g., EMA) for the longitudinal study of diverse families, and are described in detail elsewhere [24].

Phase II of the study included both participatns in the original cohort study (n=1307) who took an online survey and a sub-sample (n=631) that participated in the EMA portion of the study. Study inclusion criteria for the cohort study were: children (ages 5–9 years), without medical problems that would preclude study participation (e.g., serious mental illness), a body mass index > 5th % in the child's electronic medical records not more than three months old [25], speak English, Spanish, Hmong and/or Somali, and live full-time (> 50%) with parent completing the study. Additional eligibility criteria for the EMA portion of the study included parents reporting that they had ≥ 3 family meals/week. A lesson learned from the Phase I study was that participants preferred to use a cellphone for receiving messages, and even in the primarily low-income sample, the majority still owned a cellphone [24]. Accordingly, owning a cellphone was not a requirement for the EMA portion in Phase II, and all participants opted to use their smartphones for messages.

Eligible children and parents were recruited from primary care clinics within Minneapolis and St. Paul, Minnesota. First, parents of potential participants received a recruitment letter from the clinic; then, 1–2 weeks later, they received a follow-up phone call (in their language) from the research staff. In this phone call, the research staff confirmed the potential participant received the letter, answered any questions, reviewed the eligibility requirements, and invited study participation. After enrolling in the study, retention was maintained through obtaining multiple sources of contact information (e.g., email addresses, relative's contact), and other IRB-approved online tracking services if necessary.

The current study utilized EMA data collected during Phase II of the *Family Matters* study, which included 1307 parent-child dyads who took part in a web-based survey at two separate time points (i.e., wave 1 and wave 2), approximately 18 months apart. Participants were enrolled at baseline between 2016 and 2019, and a little over half of the participants were eligible for enrollment in the EMA portion of the study *(n* = 631). The current analysis follows reporting guidelines for EMA based on the Checklist for Reporting Ecological Momentary Assessment Studies (CREMAS, Supplemental Table 1) [26].

Measures

Ecological momentary assessment

In Phase II of the *Family Matters* study, parents used their smartphones for the EMA as all parents had their smartphones [24]. Onboarding of EMA occurred remotely and was led by the participant. In brief, after completing a web-based survey and reporting ≥ 3 family meals/week, parents were invited to participate in the EMA portion of the study. Parents were provided information on the study, and if interested they were given an access code to complete the consent and EMA registration. After registration, participants were sent a text message to ensure text capabilities were functioning. Participants were given research staff contact information to assist, though most parents completed the registration without additional assistance. A computer programmer created the EMA surveys and software program to deliver the surveys, which were delivered to both Android and iPhone iOS. Participants received the surveys as URLs in a text message [24].

Parents were asked to complete up to four surveys/day, including three signal-contingent surveys, and one end-of-the-day survey (i.e., daily diary). Signal-contingent surveys occurred randomly within fixed 3-hour windows based on the parent's sleep and wake schedules and expired 1-hour after the initial reminder. For example, the first daily survey would occur at 8:00am-11:00am, with the subsequent window being 12:00–3:00pm, and so on. The end-of-day survey was available later in the day for 4-hours. Questions occurred in the same order for all surveys. Parents were given up to three reminders for signal-contingent surveys, including the initial reminder, and reminders at 30-minutes and 45-minutes after the initial reminders. End-of-day surveys were open for 4 h, with up to four reminders occurring at 45-minute intervals if necessary. After the end-of-day survey was completed or expired, parents received a summary of their completion for the day. These sampling time frames and reminders were successful in the Phase I study [35], and similar prompting strategies (< 5 times/day) are recommended from other EMA studies of families [36]. Parents were asked to obtain 7 complete days, which would be one day that included ≥ 2 signal-contingent surveys and the end-of-day survey. Parents received $75 for having seven complete days. Phase II EMA survey questions replicated Phase I EMA survey questions, which have been published elsewhere [23, 24].

Parental stress, coping, and mood

Parental stress, coping, and mood were assessed in the first signal-contingent survey delivered that day and asked parents how they peceived their stress and ability to cope with stress. These questions were based on the Daily Health Diary as used in other parental stress-focused EMA studies [37]; this includes the Phase I study [16]. Accordingly, parents were prompted "On a scale from 0–10, with 0 being not stressed at all and 10 being very stressed, how would you rate your level of stress RIGHT NOW", with response options ranging from 0 to 10 and 10 indicating higher stress. Parental coping was queried with a similar question ("On a scale from 0–10, with 0 being ineffective and 10 being effective, how would you rate your ability to manage stress RIGHT NOW?". Parent's momentary mood was assessed using a question derived from the Kessler-6, a measure of mood and depression [38]. Specifically, parents were queried "On a scale from 0–10, with 0 being not sad or depressed at all and 10 being very sad or depressed, how would you rate your level of sadness or depression RIGHT NOW?" respectively) with similar response options to stress and coping.

Child physical activity and screen-time
Parents reported their child's physical activity and screen-time across the day at the end-of-day survey. Questions were developed based on past momentary studies in child physical activity and screen-time [39], and demonstrated agreement in the Phase I study [22]. Parents were prompted with "Today, how often DID [child's name]:" "watch TV/movies or play video games" and "exercise or engage in physical activity." Parents were given four response options, including "Never," "Rarely," "Sometimes," or "Often." These variables were treated as count variables, with a scale of 0–3 for "Never" to "Often", respectively. Changes within the child were calculated, with ranges from − 3 (decrease from "Often" to "Rarely") to 3 (increase from "Rarely" to "Often"). Responses across children and within children were considered dependent variables.

Data analysis
Descriptive statistics and frequency tabulations for panel data were computed for all key study variables to examine time-varying coverage of exposure states. Overall frequencies are reported to examine the full distribution change in child physical activity and screen time states in the sample, between frequencies report if all combinations of possible change values in child outcomes were experienced by small or large fractions of the sample over the observed person-day pairs, and within frequency proportions are reported to characterize how recurrent the observed value was over each family's observation period. For example, there was no change in boy physical activity across 598-day pairs (61.4% of days), and this was the experience of 191 boys representing 94.5% of the sample of boys ($n = 202$ total boys). The recurrence of no change in physical activity across day pairs was 66.7% indicating that about a third of the time, these boys engaged in an increase or decrease in physical activity. There was sufficient coverage of experiences of change in physical activity and screentime over days to conduct the analysis, and extreme changes in states were rare (e.g., "Never" to "Often" or vice versa).

Participants with complete data on consecutive EMA day pairs (the current and prior observation days) were retained for analysis to thoroughly examine lagged correlates of parent stress, coping, and mood on subsequent changes in child outcomes. Before completing our initial analysis and aligning with best practices for EMA [26], we explored potential correlates of compliance. These covariates included: race/ethnicity, education, income, parent and child age, parent and child sex, and parent and child overweight status. Additionally, to provide context for changes in physical activity over time (approximately 18 months), bivariate relationships between baseline survey report of child physical activity (average light, moderate, and vigorous physical activity hours/day) and average physical activity frequency reported on EMA at follow-up were estimated. Then, for our first and second aims, we used conditional fixed effects regression (within-person estimator) to examine current-day and lagged stress, coping, and mood relationships on change in child physical activity and screen-time across days [35, 40]. The model type used in this analysis was not adjusted for confounders as there were no confounders that would change across the time frame in these models (e.g., within-day or across days). Huber-White robust standard errors were computed to address the repeated measures study design, and all data management and analysis were performed in Stata 17 MP (College Station, TX). Stata software was specifically used for this research question due to the ease of computing lagged associations.

Results
The analytic sample included 436 dyads for at least one consecutive day-pair of complete data available for all key study variables (average of 4.8 day-pairs). The average survey completion time was 2.8 min (standard deviation-between participants = 1.0 min; standard deviation-within participants = 2.6 min). Only one demographic characteristic was associated with higher compliance, households with >$75K household income were more likely to be compliant than those with lower incomes ($ps < 0.05$).

Accordingly, 91% (2,952 of 3,241) of surveys were completed in the 7-day time frame. Most participants completed 6 days of the 7 possible in the first week (average: 6.77 ± 0.86), and only 5% of the sample answered 5 or fewer surveys.

Slightly more children were girls (53.7%). Children represented a variety of races/ethnicities, including White (35.7%), Black or African American (18.1%) or multiracial (18.5%), and had a household income of less than $50,000 (54.1%, see Table 1). Parents reported they were generally effective at managing stress, and their children engaged in 6–7 h/week of moderate-to-vigorous physical activity (MVPA), which is around or slightly below the guideline of 60 min/day of MVPA. The most frequently reported screens in the home were TVs, smartphones, tablets, computers, and video game counsels. Children watched a median of 2.28 h/day of screen-time. Less than half ($n = 177$, 40.6%) of children met the recreational screen-time guideline.

Table 1 Family matters sample demographics and characteristics ($n = 436$ children)

	Boys $n = 202$ (46.3%)	Girls $n = 234$ (53.7%)
Parent and Child characteristics		
Child Age, years, Mean ± SD	8.3 ± 1.3	8.4 ± 1.4
Parent Age, years, Mean ± SD	37.8 ± 6.4	38.3 ± 6.9
Child BMI Percentile, Mean ± SD	62.5 ± 28.7	64.7 ± 26.3
Child Race/Ethnicity, n (%)		
White	79 (39.1)	77 (32.9)
Black or African American	34 (16.8)	45 (19.2)
Hispanic or Latino	16 (7.9)	18 (7.7)
Asian American	25 (12.4)	20 (8.6)
Native Hawaiian or other Pacific Islander	1 (0.5)	0 (0)
Native American	12 (5.9)	25 (10.7)
Other	2 (1)	1 (0.4)
Multiracial	33 (16.3)	48 (20.5)
Parent Educational Attainment, n (%)		
Some high school	13 (6.4)	13 (5.6)
High school or Associates	59 (29.2)	74 (31.6)
Some College or Bachelors	76 (37.6)	89 (38)
Graduate Degree	54 (26.7)	58 (24.8)
Household Income, n (%)		
Less than $20,000	39 (19.3)	49 (20.9)
$20,000 - $34,999	41 (20.3)	53 (22.7)
$35,000 - $49,999	25 (12.4)	29 (12.4)
$50,000 - $74,999	26 (12.9)	27 (11.5)
$75,000 - $99,999	21 (10.4)	22 (9.)
$100,000 or more	49 (24.3)	51 (21.8)
Not reported	1 (0.5)	3 (1.3)
Parent and Child Behaviors		
Parent Ability to Manage Stress, Mean ± SD	7.1 ± 2.1	6.8 ± 2.3
Child Physical Activity, hours/week, Mean ± SD		
Mild	3.5 ± 1.6	3.5 ± 1.5
Moderate	3.8 ± 1.4	3.9 ± 1.3
Strenuous	3.6 ± 1.5	3.5 ± 1.4
Number of Screens in the Home, Mean ± SD		
TV in Home	2.2 ± 1.5	2.4 ± 1.8
TV in Bedroom	0.3 ± 0.5	0.4 ± 0.6
Smartphone	2.3 ± 1.7	2.4 ± 1.7
Tablet	1.9 ± 1.8	1.8 ± 1.6
Computer	1.6 ± 1.6	1.6 ± 1.6
Handheld Video Game	0.6 ± 1.4	0.6 ± 1.5
Video Game Console	1.3 ± 1.6	1.2 ± 1.6

^BMI = Body Mass Index, SD = standard deviation, TV = television

As shown in Table 2, many boys and girls reported a similar frequency of physical activity (66.7% and 63.4%, respectively) or screen-time (66.9% and 68.4%, respectively) across available days. It was more common to report slightly more or slightly less physical activity or screen-time, but major 2-to-3-point shifts (i.e., "Never" to "Often" or "Often" to "Never") were infrequent (< 1% each).

In bivariate models, baseline child physical activity intensities (hours/day) were correlated with more frequent EMA-reported child daily physical activity at follow-up, but the correlations for each intensity were small (mild: $r = 0.16$, moderate: $r = 0.21$, strenuous: $r = 0.18$, $ps < 0.05$, Supplementary Table 2). When all physical activity intensities were considered together in the model, moderate physical activity at baseline was the strongest correlate of reporting more frequent physical activity 18 months later.

Parental momentary stress, coping, and Mood

Parent's current day stress was negatively related to the frequency of child physical activity ($p = 0.001$), such that parents were more stressed than usual that morning, and children were less active than usual (Table 3). If the parent experienced stress that was 10 points higher, the frequency of physical activity would decrease by one point (e.g., "Often" to "Sometimes"). There were no other associations between parental stress, coping, or mood on children's physical activity or screen time, even when considering a lagged effect of the previous day's state when considering the full sample ($ps > 0.05$).

In stratified models, parental stress and coping were related to girl's frequency of physical activity ($ps < 0.05$, $n = 234$, Table 3). Previous day stress was related to more frequent physical activity the next day, while current day stress was related to less physical activity in girls ($ps < 0.05$). Higher coping strategies that day were related to less frequent physical activity in girls ($p = 0.009$). These relationships were like the overall results, where a major shift in stress (e.g., 1 to 10) would decrease their activity frequency by 1 point. There were no significant relationships between parental stress, coping, or mood on their frequency of physical activity in boys ($n = 198$), or screen-time for both sexes.

Table 2 Panel frequency tabulations for Across-Day change in physical activity and screen-time ($N = 2{,}091$ Day-Pairs)

	Boys			Girls		
Change in Physical Activity						
	Overall Frequency (%)	**Between Frequency (%)**	**Within (%)**	**Overall Frequency (%)**	**Between Frequency (%)**	**Within (%)**
Decline – 3	3 (0.31%)	3 (1.4%)	15.1%	3 (0.3%)	3 (1.3%)	17.0%
-2	37 (3.8%)	35 (17.3%)	21.5%	47 (4.2%)	42 (17.9%)	25.0%
-1	156 (16.02%)	112 (55.4%)	27.4%	190 (17.0%)	137 (58.5%)	27.3%
No Change 0	598 (61.4%)	191 (94.5%)	66.7%	640 (57.3%)	217 (92.7%)	63.4%
1	149 (15.3%)	107 (52.9%)	28.1%	181 (16.2%)	125 (53.4%)	28.4%
2	26 (2.67%)	24 (11.8%)	20.2%	53 (4.7%)	48 (20.5%)	23.0%
Increase 3	5 (0.51%)	5 (2.4%)	15.3%	3 (0.3%)	3 (1.3%)	43.6%
Change in Screen-time						
Decline – 3	2 (0.2%)	2 (0.9%)	19.6%	1 (0.1%)	1 (0.4%)	16.7%
-2	27 (2.7%)	26 (12.8%)	19.0%	32 (2.8%)	30 (12.8%)	23.4%
-1	163 (16.7%)	101 (50.0%)	31.6%	188 (16.8%)	131 (56.0%)	28.2%
No Change 0	593 (60.8%)	189 (93.5%)	66.9%	688 (61.6%)	217 (92.7%)	68.4%
1	158 (16.2%)	116 (57.4%)	28.1%	169 (15.1%)	116 (49.5%)	28.0%
2	29 (2.9%)	26 (12.8%)	19.3%	38 (3.4%)	34 (14.5%)	25.0%
Increase 3	2 (0.2%)	2 (0.9%)	18.3%	1 (0.1%)	1 (0.4%)	16.6%

Discussion

The purpose of this study was to examine the associations between parents' lagged and same day stress, coping, and mood and children's physical activity and screen-time, and whether these associations differed by sex. Overall, when parents reported higher levels of stress than usual, children were less active that same day. Parents' stress and coping were especially important for girls' physical activity, not boys. Findings suggest that reducing parental stress and improving coping abilities may improve girls' physical activity, but other approaches are needed to reduce child screen time and improve boys' physical activity at this age.

Our hypothesis that higher levels of parent stress would be related to less child physical activity was supported in the current investigation and aligns with past observational literature [9, 10]. These findings also align with past EMA investigations that found higher than normal parent stress was related to poorer parenting practices, such as less physical activity parenting practices 2-hours later [15], and higher pressure-to-eat that night [16]. Expanding upon this past literature, this study found these relationships were specific to parental stress state, not their mood. Parental mood assessed in this study was about depressed mood, though others have commonly examined another parental state of negative affect or feelings of emotional distress. Another EMA study found parental negative affect was negatively associated with physical activity in slightly older children (ages 10–12 years) but not younger children (ages 8–10 years) [41]. The exact mechanism is unclear, as a systematic review of EMA studies found negative affect was not associated with subsequent physical activity in adults, positing it is likely not through a reduction in their physical activity [42]. These findings may suggest that at the current age assessed in this study (i.e., 5–9 years) a parent's depressed mood may not affect a child's physical activity like stress does, but it may be important when the child is older.

Our hypothesis that parental stress and stress-related psychological factors (i.e., stress, mood) would be associated with screen time was not supported. The lack of relationship between parental states and child screen time in this study may be due to the younger age (< 10 years), as this relationship is consistently found in older children (ages 8–17 years) in observational studies [43]. It is more likely that this relationship may reflect the dynamic nature of parental stress and screen-time across the day. Another EMA study found that parents may maintain screen-limiting practices in the 2-hours following higher-than-normal stress [15], thus resulting in less child screen-time in those 2-hours. The current protocol queried screen-time across the entire day, rather than momentary associations with subsequent child behavior. It may be proposed that parents allow more screen-time later in the day, which negates the earlier reduction in screen-time and results in the same overall screen-time amount. These findings highlight daily opportunities to promote less screen-time, along with in-the-moment solutions.

We found support for our hypotheses that parental state was related to girls' physical activity, along with a complex relationship between parental stress and coping. These results propose that after a day of high stress and managing stress (i.e., coping), girls are slightly more active. On the current day of higher stress, parents may engage in coping behaviors rather than activity with the

Table 3 Within- and across-day stress, coping, and mood on child physical activity and screen-time ($n = 436$ parents with 2,079 day-pairs)

	Child Physical Activity			Child Screen-time		
Predictor	**β for Change in Frequency**	**95% CI**	**P Value**	**β for Change in Frequency**	**95% CI**	**P Value**
Overall Sample (n = 436)						
Parent Stress Level						
Lagged	0.017	(-0.02, 0.06)	0.42	0.014	(-0.02, 0.05)	0.47
Current Day	-0.073	(-0.12, -0.03)	0.001*	-0.022	(-0.06, -0.06)	0.30
Parent Coping						
Lagged	-0.005	(-0.04, 0.03)	0.77	0.012	(-0.02, 0.04)	0.45
Current Day	-0.024	(-0.06, 0.01)	0.20	-0.008	(-0.04, -0.04)	0.65
Parent Mood Level						
Lagged	0.004	(-0.05, 0.06)	0.89	-0.019	(-0.07, 0.03)	0.46
Current Day	0.008	(-0.05, 0.06)	0.78	0.012	(-0.04, -0.04)	0.63
Boys (n = 202)						
Parent Stress Level						
Lagged	-0.052	(-0.11, 0.01)	0.09	0.027	(-0.03, 0.09)	0.35
Current Day	-0.033	(-0.1, 0.03)	0.32	-0.031	(-0.09, 0.03)	0.32
Parent Coping						
Lagged	-0.02	(-0.07, 0.03)	0.42	0	(-0.05, 0.05)	0.99
Current Day	0.028	(-0.02, 0.08)	0.28	0.001	(-0.05, 0.05)	0.97
Parent Mood Level						
Lagged	0.032	(-0.05, 0.11)	0.42	-0.031	(-0.11, 0.04)	0.41
Current Day	0.014	(-0.07, 0.1)	0.74	-0.005	(-0.08, 0.07)	0.89
Girls (n = 234)						
Parent Stress Level						
Lagged	0.069	(0.01, 0.13)	0.018*	0.003	(-0.05, 0.05)	0.91
Current Day	-0.106	(-0.17, -0.05)	0.001*	-0.015	(-0.07, 0.04)	0.59
Parent Coping						
Lagged	0.007	(-0.04, 0.06)	0.77	0.025	(-0.02, 0.07)	0.29
Current Day	-0.071	(-0.13, -0.02)	0.009*	-0.017	(-0.07, 0.03)	0.49
Parent Mood Level						
Lagged	-0.027	(-0.1, 0.05)	0.48	-0.009	(-0.08, 0.06)	0.80
Current Day	0.005	(-0.07, 0.08)	0.88	0.025	(-0.04, 0.09)	0.46

^Assessed using conditional fixed effects regression; *$p < 0.05$

child, thus resulting in less child physical activity [44]. Boys may be protected from these responses since they are more likely to participate in sports at this age [45], which may not be impacted by parental stress. Instead of physical activity, girls may then spend time in solitary or less active pursuits (e.g., coloring), as there were no associations with screen-time in the current study. This evidence may support others who found mothers who experienced chronic stress reported more screen-time in boys 2-years later, but not girls [43, 46], indicating that momentary stress may also have a disproportionate impact on healthy behavior. There is limited evidence in lagged associations, but one EMA study of adults found that lower stress days preceded more active days [19], which is contrary to our findings. This prior study sampled stress at a random time during the day [19], whereas the current study focused on responses during the first interval (e.g., 8:00am-11:00am). It may be that parents resolve their stress later that day, which allows them to facilitate the girl's physical activity the next day, potentially through their physical activity. A similar phenomenon was observed in a longitudinal study, whereby higher stress was related to an increase in maternal sleep 2-months later [47], but not fathers, potentially through the mechanism of the mother making changes to decrease stress and facilitate more sleep. Specific to this EMA study, a smaller timescale of parental stress and child physical activity may improve upon our understanding of this relationship. Additional exploration into lagged associations between parent stress and child behavior may reveal this pathway.

Strengths of the current study include the use of advanced methodology (i.e., EMA) to examine within-day and lagged associations, assessment of multiple parental states related to stress, the racial and ethnic diversity of the sample (64.3% non-white), and the Phase I study data within the population to test EMA study procedures [24]. A limitation is that EMA data is a short self-report (i.e., subjective measure) and may be improved by completing the longer questionnaires to fully assess parental state or potentially device-based measures for stress and health behaviors. Even so, others have found self-reported measures of stress are related to subsequent physical activity rather than objective measures of stress [17]. Device-based measures are correlated with physical activity [22], as demonstrated in the comparison of survey methods and EMA in this sample. Another limitation is the screen-time assessment was predominantly video games, TVs, and computers, which may omit time spent on other devices (e.g., tablets). However, these devices are the most common sedentary screen-time activities and the main basis of the 24-hour movement guidelines recently adopted by the World Health Organization [6, 48]. Parental mobile screen use is a well-established correlate of child mobile screen use and may be related to their stress [49], and should receive strong consideration in future studies. The diversity of the sample, as well as the large EMA sample size, is a strength, but results may still not generalize to populations with different sociodemographic characteristics than in our sample. A final limitation is the ability to compare our results to other EMA investigations of parents and children, given the various sampling methodologies, and questionnaires used. A unified approach to EMA methodology across researchers may improve this practice, but flexibility is also needed to tailor it for differing populations.

Results from this study posit six principal areas for future research, policy, and practice. First, a detailed investigation into the relationship between parental stress and coping strategies is recommended; this may be achieved through mixed methods to understand the temporality and application in real-life situations [9, 23]. Second, investigation into the context (i.e., when, where, and with whom) and using device-based measures on a smaller time scale may clarify the immediate mechanism of parental stress on child physical activity and screen-time. Obtaining additional information from self-report items of context (e.g., stressors and location), passive sensing devices (e.g. heart rate variability [21]), or using geolocation may help reduce social desirability bias and inform future interventions [50]. Third, consideration of screen-time, including content (educational, homework), device used (cellphones, iPad), and other seated activities (coloring, homework) may better contextualize time spent sedentary. Fourth, these results support the development of real-time or ecological momentary interventions (EMI) to address parental mental state to help protect against low amounts of child physical activity. Fifth, multi-level support is required to facilitate girls' physical activity, which may include policies (e.g., school recess) and programs (e.g., after-school options) that promote consistent physical activity at this young age range. Given girls are already less likely to be active at this age, providing organized sports or other structured options for girls may benefit both parent and child. Finally, given participants were recruited from the clinic, further exploring the role of the provider in supporting parents' mental state and educating on the importance of child physical activity at this age, especially in girls, should be considered.

Conclusions

This investigation found that on days when parents were stressed much more than usual early in their day, their child was less physically active that day overall; however, the child had more activity the next day. Parental stress, on that same day or the day prior, did not translate into the child spending more time watching screens. Parents' stress and ability to manage stress are especially important for girls' physical activity, but less so for boys. Opportunities to reduce parental stress and support girls' physical activity may help improve health for both parent and child.

Abbreviations

CREMAS	Checklist for Reporting Ecological Momentary Assessment Studies
EMA	Ecological Momentary Assessment
MVPA	Moderate-to-vigorous physical activity
TV	Television

Supplementary Information

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Supplementary Material 1

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Author contributions

CLK developed the research question, drafted the initial manuscript, and reviewed and revised the manuscript. ATa carried out data analyses, reviewed and revised the manuscript. JNdB helped develop the research question, contributed to initial manuscript creation, and reviewed and revised the manuscript. ATr was a major contributor in writing the manuscript and interpretation of data, reviewed and revised the manuscript. JB conceptualized and designed the Family Matters study, designed the data collection instruments, help develop the research question and analysis plan, and critically reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The University of Minnesota provided institutional review board and ethics approval (IRB#: STUDY00014631). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent to participate of the parent/guardian and written assent to participate of the adolescent was obtained at the orientation meeting, and from all participants in the study prior to study procedures.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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