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The home environment and toddler physical activity: an ecological momentary assessment study

E.R. Hager[1,2], **N.A. Tilton**[1,2], **Y. Wang**[1], **N.C. Kapur**[1,3], **R. Arbaiza**[1], **B.C. Merry**[4], and **M.M. Black**[1,2]

[1]Department of Pediatrics, University of Maryland School of Medicine, Baltimore, MD, USA

[2]Department of Epidemiology & Public Health, University of Maryland School of Medicine, Baltimore, MD, USA

[3]Wayne State University School of Medicine, Detroit, MI, USA

[4]Department of Psychiatry, Yale University School of Medicine, New Haven, CT, USA

Summary

Background—Physical activity (PA) promotion/obesity prevention in toddlerhood should include home environments.

Objective—The aim of the study was to determine social/physical home environment factors associated with toddler PA using ecological momentary assessment (EMA, real-time data collection).

Methods—Low-income mother–toddler dyads were recruited and given a handheld EMA device (53 random beeps followed by social/physical environment survey over 8 d). Simultaneously, PA was assessed via accelerometry (data extracted 15 min before/after response, average activity counts per minute). Linear mixed-effects models were used, adjusting for toddler age, urban/suburban residence and time of day; covariate moderating effects were examined; within-subjects and between-subjects findings were reported. PA was hypothesized to be greater when toddlers are outside (vs. inside), children are nearby (vs. alone), toddlers are interacting with their mothers (vs. not) and TV is off (vs. on).

Results—The final count was 2454 EMA/PA responses for 160 toddlers (mean age 20 months, range 12–31; 55% male, 66% Black and 54% urban). Associations with PA include (within subjects) the following: outside location (212 additional counts min^{-1}), children nearby (153

Address for correspondence: ER Hager, PhD, Department of Epidemiology & Public Health, University of Maryland School of Medicine, 737 West Lombard Street, Room 163, Baltimore, MD 21201, USA. ehager@peds.umaryland.edu.

Author contributions

E. H. conceived this study and worked with N. T., R. A., B. M. and M. B. to design the study. E. H. oversaw the analysis/interpretation and was the primary author of the written content. N. T. conducted the statistical analyses, interpreted findings and contributed to the written content. N. K. contributed to interpretation and written content. R. A., B. M. and M. B. were instrumental in the acquisition of data. All authors revised the article for important intellectual content and read/approved the final version.

Conflict of Interest Statement

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additional counts min^{-1}) and interacting with mother (321 additional counts min^{-1}), compared with alternatives. Age was moderated by outside location/PA association (within subjects), with 90 additional counts min^{-1} per 3-month age group outside vs. inside. No between-subjects or television/PA associations were found.

Conclusions—Home environment factors were associated with PA, including outside location, children nearby and mother interaction. EMA is a novel method, allowing identification of contextual factors associated with behaviours in natural environments.

Keywords

Outdoor play; maternal interaction; very young children; accelerometry

Introduction

Paediatric obesity is a public health problem in the USA affecting all children, including the very young (<5years of age). In 2011–2012, 8.1% of children <2 years of age and 8.4% of children 2–5 years old had weight-for-recumbent length/body mass index-for-age ≥ 95th percentile, respectively (1). Recent longitudinal studies have shown that excess weight gain before age 5years is maintained throughout childhood (2), increasing risk for obesity and related co-morbidities later in life. In response, recommendations are to implement obesity-prevention programmes among very young children and their families.

A physically active lifestyle established early in life promotes positive health behaviours and prevents obesity (3). Recent physical activity (PA) guidelines from the United Kingdom, Canada and Australia recommend 180 min d^{-1} of PA of any intensity (light, moderate or vigorous) for toddlers (age 12–36months) (4–6). Investigating home environment factors associated with PA in toddlerhood will contribute to a better understanding of how the home environment may influence risk for childhood obesity and prevention measures that can be recommended.

Recall errors and biases can negatively impact the ability to collect valid and reliable data on PA behaviours of young children because of the reliance on parents to provide a proxy report (7). Objective methods of assessing PA, such as accelerometry, are unable to provide information on PA type or context (8). One strategy for improving the accuracy of proxy-reported behaviours among toddlers and eliminating recall bias, while collecting information on the context of behaviours, is ecological momentary assessment (EMA).

Ecological momentary assessment is a method of real-time data collection in which participants report on behaviours and/or context of behaviours at multiple time points in their natural environment (9). EMA is a valid approach to providing the social and physical context of PA among children and adolescents (10,11), and an ideal tool for examining home environment factors related to behaviour in real time. A recent study using EMA found that being outside and around other children are associated with higher PA among school-aged children (10). Other home environment factors associated with PA have yet to be explored, and, to our knowledge, no EMA study has focused on contextual factors influencing PA in toddlerhood.

The Conceptual Model for Eating and PA Environmental Influences in the Home describes how social and physical factors in the home environment relate to diet and PA behaviours, which then influence obesity risk (12). This model provides a framework for describing relations between the home environment and toddler behaviour. Drawing on the tenets of the developmental ecological theory (13), it is found that toddlers are dependent on proximal relations with family members for opportunities to engage in healthy behaviours. These models support the need to identify social and physical factors in children's environment that relate to PA to develop context-specific health-promotion/obesity-prevention interventions.

This study aims to identify factors in the home environment associated with toddler PA. The mother's real-time report of aspects and events in the home environment collected via EMA in conjunction with objectively measured toddler PA (accelerometry) is used to test four hypotheses based on the conceptual model: toddlers are more active when (i) outside vs. inside, (ii) other children are nearby vs. alone, (iii) interacting with the mother vs. not interacting and (iv) the television is off vs. on. Additionally, the moderating effect of toddler gender, age and recruitment location (suburban vs. urban) is examined.

Methods

Recruitment

Biological mothers and their toddler-aged children (12–32 months, born at term, birth weight >2500 g and able to walk independently) were eligible and recruited to participate in a longitudinal Toddler Obesity Prevention Study (TOPS) from two sites: a Special Supplemental Nutrition Program for Women, Infants, and Children clinic in a suburban Mid-Atlantic county and an inner-city paediatric clinic serving predominantly low-income families. Baseline TOPS data are presented here, collected between 2007 and 2010, accounting for all seasons. Mothers provided written informed consent and completed self-administered, computer-based questionnaires using voice-generating software. Institutional review boards from both the university and state Department of Health approved this study. Evaluations were conducted during two separate visits, ≥1 week apart, by trained research assistants. Mothers reported their toddler's birth date, gender and race/ethnicity and their own birth date, marital status, education, employment and the number of household members/annual household income (used to calculate a poverty ratio (14)).

Anthropometrics

Mothers undressed their toddler to a clean diaper/underpants. Weight (kg) and recumbent length (cm) were measured in triplicate using a Tanita 1584 Baby Scale (Tanita, Tokyo, Japan) and a Shorr Measuring Board (Shorr Productions, Olney, MD, USA). Gender-specific body mass index-forage percentiles were calculated according to World Health Organization growth charts. Overweight was defined as ≥97.7th percentile (15).

Ecological momentary assessment

Mothers of toddlers were given a Palm Z22 (Palm, Inc., Sunnyvale, CA, USA) handheld personal digital assistant that beeped 53 times over 8 d (no more than 8 times per day)

between 8:30 AM and 8:30 PM. Prompts were scheduled to occur at intervals throughout the day. Because participants were unaware of the beep schedule, the prompts were perceived to occur randomly. A signal-contingent sampling scheme was used wherein participants were asked to complete a questionnaire following a random auditory prompt (the personal digital assistant beep). EMA data recorded within 15 min after each beep were retained.

The toddler portion began by asking if the toddler was with the mother (if no, the questionnaire ended) or asleep (if yes, the questionnaire ended, given the focus on context of toddler behaviours). The questionnaire contained items about the mother and child's current food consumption, PA and environment (maximum length = 21 items). Home environment factors were chosen based on the literature regarding PA context (10,16,17) and are listed in Table 1.

In addition to analysing each EMA response as an event (described subsequently), compliance (% with EMA data, responding to ≥ 1 beep), adherence (proportion of responses) and toddler compliance (% with EMA data, toddler with mother and awake, responding to ≥ 1 beep) and adherence (proportion of toddler responses) scores were generated. Missing EMA data were explored by both time-varying (time of day, chronological day of the study) and time-invariant (mother/toddler demographics) factors.

Accelerometry

An Actical (Philips Respironics, Bend, OR, USA) accelerometer was placed on the non-dominant or left ankle, superior to the lateral malleolus, with a non-removable, reinforced hospital band during the first visit (18). Toddlers wore the accelerometer for ≥ 7 consecutive days (24-h periods), next to the skin, under socks. Activity counts were collected in 1-min intervals to mirror maternal PA data collected simultaneously (18). During the second visit, the band was removed. Data were reduced using software provided by the ACTICAL manufacturer (version 2.12). Only complete days (i.e. full 24-h periods) were retained. For >7 full days, data were truncated after the seventh day. Days with a daily average of <80 counts were considered incomplete and removed.

Accelerometer data were analysed as average raw activity counts per minute, isolated from 15 min prior to and following the moment a valid EMA response was provided (total time 31 min).

Statistical analysis

Chi-square and *t*-tests were used to assess demographic differences in adherence rates and by inclusion/exclusion in the final sample. Simple proportions and means of demographics and EMA responses were calculated. Linear mixed-effects regression models with random intercepts and unstructured covariance matrices were used to address clustering because of repeated measures of EMA responses and activity counts. All hypothesized home environment factors (predictors) are time varying and varied both between subjects (average) and within subjects (each individual, across time). To disaggregate the within-subject and between-subject relations, both the (i) person-centred mean and (ii) time-specific deviation from the person-centred mean of the predictors were included in the models (19,20). Activity counts were skewed and normalized through log transformation. Models were run

with the normalized and non-normalized outcome, with direction and significance of results remaining the same; thus, the non-normalized outcome is presented in the results to ease interpretation. Toddler gender, age and recruitment location (factors shown to be associated with toddler PA (18)) were examined as covariates, with gender removed from the models because of non-significant findings. Age was considered a proxy for motor skills development and examined in 3-month bins (i.e. 12–15 and 15–18 months) for ease of interpretation based on development by age. Time-varying covariates (time of day/day of week) were examined, with day of week (weekdays vs. weekends) removed because of non-significant findings. The moderating effect of gender, age and recruitment location on the relationship between home environment constructs and PA was examined in adjusted models by creating interaction terms. Analyses were performed using SAS 9.3 (SAS Institute Inc, Cary, NC, USA).

Results

Sample description

Two hundred seventy-seven mother–toddler dyads were enrolled. Seventeen toddlers did not have complete EMA data (≥1 beep answered), and 102 did not have valid accelerometry data (≥1 d). Primary reasons for missing accelerometry data are as follows: mother refusing the accelerometer for their toddler ($n = 38$), wear time of <2 d ($n = 30$) and improper programming and documentation ($n = 11$) (18). The final sample size included 160 mother–toddler dyads. Compared with those excluded, included mothers were younger (26.6 vs. 28.2years, $t = 2.1$, $p = 0.035$) and more likely to be suburban (69.2% vs. 53.8%, $t = 6.8$, $p = 0.010$) and have a high school diploma/equivalent (85.0% vs. 75.2%, $t = 4.2$, $p = 0.041$). There were no differences by toddler demographics or other maternal factors.

The sample is described in Table 2. The majority of toddlers were <24 months of age, nearly half were male, two-thirds are African–American or Black and 10% are overweight. Mothers were, on average, 26 years old, most were not married, the majority had a high school diploma/equivalent and over half were unemployed. Most families were living at/below the federal poverty level, over half were recruited from the urban site and the mean number of children/household was 2.4.

Using ecological momentary assessment to examine the home environment

Maternal EMA compliance was 94% (260/277), and adherence was 52% (7119/13 780), with mean individual adherence of 35% (range: 2–83%). Toddler EMA compliance was nearly 100% (259/260), and adherence was 72% (5048/7119). Individual EMA adherence rates were similar across time of day (morning, 35.5%; afternoon, 34.1%; and evening, 35.8%) and were highest on study day 2 (46.4%), declining to 29.0% on day 7. Adherence rates on the first and last days (1 and 8) were lower (32.8% and 13.5%, respectively), likely because of timing of evaluations. Adherence varied by time-invariant factors, with mothers who were married, suburban, White and unemployed and mothers of male and healthy weight toddlers having significantly higher adherence rates compared with their counterparts ($p < 0.05$). Other factors, including maternal and toddler age, socioeconomic status and maternal education were not associated with adherence. For this study, EMA responses

included in the analysis were limited by those with valid accelerometry data (63.2% of the sample), leading to a final count of 2454 beeps answered for 160 mother–toddler dyads.

The proportion of the total EMA responses affirmatively endorsed is presented in Table 1. For example, among the 2454 beeps that were answered when the child was present, 8.4% occurred when the toddler was outside and 55% when the mother was interacting with her toddler.

Association between home environment and toddler physical activity

In Table 3, results from the mixed-effect models display within-subject and between-subject differences in activity counts related to affirmative vs. negative responses to the four EMA questions representing each of the home environment constructs hypothesized to be associated with toddler PA.

For within-subject effects, for a given toddler, mean observed activity was 153 counts min^{-1} higher when in the company of other children compared with times when other children were not present (95% confidence interval [CI]: 61, 256; $p = 0.001$). At times when the mother reported interacting with the child, estimated mean activity was 321 counts min^{-1} higher (95% CI: 273, 368; $p < 0.001$) compared with times when no such interaction was reported. Being outside accounted for an increase of 212 counts min^{-1} compared with being inside (95% CI: 126, 298; $p < 0.001$). No within-subject difference in activity counts was observed when the television was reported to be off (vs. on). There was no significant between-subject relation for each of the four EMA home environment constructs and toddler PA.

An age by location interaction was observed within subjects in relation to average activity counts per minute. The relation between PA and outside location was stronger among older children compared with that among younger children. In other words, outside location accounted for 90 more counts min^{-1} than inside location with every 3-month increase in age (95% CI: 61, 120; $p < 0.001$). Other hypothesized associations were examined for a moderating effect of gender, age or recruitment location with no significant findings.

Discussion

This study sought to identify factors in the home environment associated with toddler PA using a novel approach to gather data on the context of PA in the home environment. EMA has been used to examine factors associated with PA among children and adolescents (8,10,11), with participants responding to the EMA prompts for themselves. In this study, mothers reported contextual information for their toddler, providing a proxy report of the home environment. By combining time-stamped, incident-based, maternal-reported home environment data with objectively measured PA data for the toddler, we were able to uniquely examine home environment factors associated with PA among individual toddlers (within subjects) and across toddlers (between subjects) (21).

This study was based on the Conceptual Model for Eating and PA Environmental Influences in the Home, which provides a framework for describing relations between the home

environment and toddler behaviour, emphasizing social and physical factors of the PA home environment (12). Our hypotheses examined four contextual variables, beginning with the toddler's location. Toddlers were more active when outside vs. inside (within subjects), a finding that has been reported among school-age children using EMA (10) and among pre-school in childcare settings (22,23). This association was moderated by age, such that older toddlers were more active when outside, compared with younger toddlers and being inside. This suggests that toddlers, regardless of developmental stage, are equally inactive when inside; however, when outside, those with more advanced motor skills (older toddlers) have the opportunity to engage in higher levels of PA. There are many barriers to outdoor play, particularly for low-income families, given that low-income neighbourhoods have reduced access to recreational facilities and no-cost programming (24). Programmes and policies should aim to reduce barriers to outdoor play among low-income toddlers to increase PA.

In support of our second hypothesis, toddlers were more active when other children were nearby vs. alone (within subjects). Given the wide developmental changes that occur between 12 and 32 months of age, including evolving from independent to imaginary/interactive play, implications of this finding suggest that toddlers, regardless of age, are more likely to be active when with other children. Promoting developmentally appropriate interactions with other children has been shown to benefit the development of young children (25) and, based on the findings from this study, may also increase the likelihood of being physically active.

Third, in support of our hypothesis, toddlers were more active when interacting with their mother vs. not interacting (within subjects). A study examining longitudinal predictors of toddler PA found that mother–child interactions in the context of PA co-participation in infancy led to higher PA in toddler-hood (26). Our study does not parse out what the mothers and toddlers were doing together, simply that they are interacting. Positive parent–child interactions are associated with developmental skills (27) and reduced risk for obesity (28). This study supports that an added benefit of parent–child interactions among toddlers may be increased PA.

Finally, contrary to our hypothesis, having a television on in the room was not associated with toddler PA in neither within-subjects nor between-subjects analyses. A prior study of preschool-aged children found that PA was higher among those with limited television viewing (29). We asked whether the television was on in the area where the toddler was located. Additional information was not gathered regarding whether the child was watching the television or type of programming. Descriptive findings show the television was on near the toddler for nearly half of the responses, raising questions about television exposure/television as background noise. We did not inquire about media/screen use to which toddlers are more recently exposed (e.g. smartphones and tablets), and this should be explored.

With EMA studies, both within-subjects and between-subjects findings should be presented to disentangle effects (21). When an EMA study relies solely on random prompts, as in the study described here, within-subjects findings are more meaningful. For example, the significant within-subject finding of PA related to location means that individual toddlers, followed up repeatedly over time, were more active when outside vs. inside. For the

between-subjects analysis, the non-significant PA/location findings suggest that the average PA of the sample of toddlers did not differ by the average reported location; however, the location variable is not balanced (the proportion of times a mother reported that her toddler was inside vs. outside was random). Prescribed prompts (i.e. 'please respond when outside') may capture more meaningful between-subjects data (indicating which toddlers are outside more often). Given the current study design, relying only on random prompts, within-subjects findings reveal more information on how individual behaviour varies in relation to context over time.

In addition to primary findings, this study introduces the use of EMA to gather incident-based data among low-income families with young children. The volume and quality of the data collected suggest that this method may be employed in future studies examining contextual factors associated with toddler behaviours. Additionally, beyond data collection, handheld mobile devices may be used as intervention tools to prevent obesity in children (often referred to as mobile health or 'M-Health') (30). The findings from this study support the exploration of using M-Health strategies targeting toddler-aged children.

Strengths and limitations

The use of EMA paired with accelerometry and the focus on toddler-aged children are strengths. The mother's adherence (52% overall, 35% individually) was lower in this study compared with other studies (81.6% (8) and 72.5% (31) among school-aged children and adolescents, respectively). Adherence varied by demographic factors, suggesting that generalizability may be limited. Adherence was further reduced owing to proxy reporting. The adherence rate is consequently a limitation; however, over 2400 responses were recorded. Valid accelerometer data were missing for ~1/3 of the sample. Inclusion/exclusion analyses yielded few demographic differences, reducing the likelihood of selection bias. Accelerometer counts were recorded in 1-min intervals, which is too large to capture sporadic activity. Few investigators have employed accelerometry to examine toddler PA in community studies (18,32); thus, this method should be examined further. Finally, the study population was exclusively low income, with two-thirds living at/below the poverty level. This limits broad generalizability, although the sample did include a racial/ethnic mix and both urban and suburban sites, extending generalizability to other low-income families.

Conclusions

Factors in the home environment were associated with toddler PA, including outside location, other children nearby and mother–child interaction. Television exposure was not associated with toddler PA. This study used EMA paired with accelerometry, a novel approach that allows researchers to capture contextual factors associated with behaviours in natural environments. These findings could inform future home-based toddler obesity-prevention programmes.

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Abbreviations

EMA	Ecological Momentary Assessment
PA	Physical Activity
TOPS	Toddler Obesity Prevention Study
WIC	Special Supplemental Nutrition Program for Women, Infants, and Children
PDA	Personal Digital Assistant

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Table 1

Ecological momentary assessment responses

Construct	Question	Response list	Proportion
Physical location	Are you…	Inside; outside; in a vehicle (car, bus, cab)	8.4% (outside)
Children nearby	How many children are in the room/area?	None; 1; 2; 3; 4 or more	92.4% (two or more)
Interaction with mother	Are you talking, singing or playing with your child right now?	Yes; no	55% (yes)
Television on/off	Is the TV on in the area where your child is?	Yes; no	45.6% (yes)

Table 2

Sample description (n = 160)

		Mean ± SD/(range) or %
Physical activity	Activity counts (counts min^{-1})	388.0 ± 145.6
Toddler age	Months	19.9 (12.0–31.6)
	≤24 months	75.6%
	>24 months	24.4%
Toddler gender	Female	45.0%
	Male	55.0%
Toddler race	African–American or Black	65.6%
	White or Caucasian	23.8%
	Hispanic or Latino	1.9%
	Other	8.8%
Toddler body size	Healthy weight (<97.7th percentile BMI-for-age)	90.0%
	Overweight (≥97.7th percentile BMI-for-age)	10.0%
Maternal age	Years	26.6 (18.0–43.6)
Marital status	Married	28.8%
	Single	67.5%
	Divorced	3.8%
Education	Less than high school	15.0%
	High school diploma/equivalent	34.4%
	Some college	36.9%
	College or graduate degree	13.7%
Employment	Employed part/full-time	36.9%
	Unemployed	63.1%
Socioeconomic status	Living above federal poverty ratio	33.5%
	Living at/below federal poverty ratio	66.5%
Recruitment location	Suburban	46.2%
	Urban	53.8%
Household composition	Number of children	2.4 (1–6)

BMI, body mass index.

Table 3

Linear mixed-effects regression assessing relationship between caregiver's ecological momentary assessment responses and child's measured activity[1]

		Between subject			Within subject		
		Estimate	**Standard error**	**p**	**Estimate**	**Standard error**	**p**
Time-varying predictors	Children nearby: yes	3198.1	231.7	0.393	153.3	47.1	0.001
	Interacting with mother: yes	163.7	127.9	0.201	320.7	24.2	<0.0001
	Television: on	89.4	87.0	0.304	38.4	26.6	0.753
	Physical location: outside	3109.4	217.3	0.615	212.1	43.9	<0.0001
	Age group physical location (outside)[2]	—	—	—	90.1	15.0	<0.001
Time-invariant covariates	Recruitment location: suburban	113.1	48.2	0.019			
	Age group	48.2	13.6	< 0.001			
Time-varying covariates[3]	Morning[4]	51.9	30.0	0.084			
	Evening[5]	141.5	27.5	< 0.0001			

[1] Activity counts/minute (non-normalized) are presented for ease of interpretation; when normalized activity variable is used (log-transformed), significance and direction of results remain the same.

[2] The interaction coefficients presented were estimated based on a model including age group, physical location, their interaction, and other variables in the table; additional coefficients presented in the table are from a model excluding the interaction term.

[3] Within/between subject effects for time-varying covariates are not disaggregated.

[4] Hours of 0830 to 1159 (reference = 1200 to 1559).

[5] Hours of 1600 to 2000 (reference = 1200 to 1559).