Preventive Medicine Reports 8 (2017) 197–203

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Associations between mother's and children's moderate-to-vigorous physical activity and sedentary time in the family context

MinKyoung Song[a,b,*], Nathan F. Dieckmann[b,c], Sydnee Stoyles[b], Youngwon Kim[d], Julie C. Lumeng[e]

[a] School of Nursing, University of Michigan, Ann Arbor, MI, United States
[b] School of Nursing, Oregon Health & Science University, Portland, OR, United States
[c] School of Medicine, Oregon Health & Science University, Portland, OR, United States
[d] MRC Epidemiology Unit, University of Cambridge School of Clinical Medicine, Cambridge, United Kingdom
[e] Department of Pediatrics, Medical School, Department of Nutritional Sciences, School of Public Health, Center for Human Growth and Development, University of Michigan, Ann Arbor, MI, United States

A R T I C L E I N F O

Keywords:
Physical activity
Sedentary time
Home environment

A B S T R A C T

The manner in which mothers' and children's moderate-to-vigorous physical activity (MVPA) and sedentary time (ST) are associated across different settings (i.e., at home versus outside of the home, on weekdays versus weekends) is not well understood. The purposes of this study were to: (Strong et al., 2005) describe associations between mothers' and children's levels of MVPA and ST, and (U.S. Department of Health and Human Services, 2008) determine how setting and mothers' and children's characteristics moderate the associations. We used baseline data from the University of Michigan Healthy Families baseline data (2013–2015) from 55 mothers who have children in two age groups (3–5.99 years [n = 25] and 10–12.99 years [n = 30]) for the analysis. MVPA and ST data were collected using accelerometry over a seven day period. Proportion of time spent in MVPA and ST between 08:00 am and 08:59 pm was calculated. Mixed-effects models were used to examine associations. After controlling for selected mother and child characteristics and setting variables, MVPA and ST levels were positively associated in mothers and their children ($P < 0.001$). The mother-child associations for MVPA and ST were 1.7 times ($\beta = 0.365$ versus $\beta = 0.216$) and 2.2 times ($\beta = 0.255$ versus $\beta = 0.117$) stronger, respectively, when both were at home together. The association did not differ by day of the week. The variations by setting underline the importance of developing home-based, family-centered interventions to increase PA and decrease ST.

1. Introduction

Physical activity (PA) confers health benefits to children (Strong et al., 2005; U.S. Department of Health and Human Services, 2008). Nonetheless, reports show that a large proportion of children do not meet current PA guidelines (i.e., at least 60 min of PA daily (U.S. Department of Health and Human Services, 2008)) (Kann et al., 2016; Chung et al., 2012; Song et al., 2013). Relatedly, sedentary time (ST) is independently associated with negative health outcomes such as obesity and cardiometabolic risk (Saunders, 2014; Tremblay et al., 2011) and although there are no formal guidelines for ST in children, evidence shows that ST increases in youth as they get older: (Janssen et al., 2016; Pearson et al., 2017) Youth at age 7 years average just over 50% of their waking hours in sedentary behaviors, with that amount increasing to over 75% of the waking day in youth aged 15 years. Thus, improved methods for enhancing PA and limiting sedentary behaviors in children are needed, and implementing such methods while children are still young will have long-term benefits.

While considering parent-child interactions when addressing childhood health behaviors is often discussed in children's health literature, there remain gaps in our understanding of the relationship between parents' and children's PA and ST. (Jago et al., 2010; Trost et al., 2003) Studies on whether any association exists have not had uniform findings (Hesketh et al., 2014; Ruiz et al., 2011; Jago et al., 2014a; Fuemmeler et al., 2011) and evidence regarding factors that could explain potential associations between parents' and their children's PA and ST is limited. There is some evidence to suggest that gender is an influence (with strong associations for PA levels between boys/fathers and girls/mothers, respectively) (Jago et al., 2010; McMurray et al., 2016) and that there are stronger associations in PA

* Corresponding author at: Oregon Health & Science University, School of Nursing, 3455 SW US Veterans Hospital Road, Portland, OR 97239, United States.
E-mail address: songm@ohsu.edu (M. Song).

http://dx.doi.org/10.1016/j.pmedr.2017.10.012
Received 20 February 2017; Received in revised form 4 September 2017; Accepted 16 October 2017
2211-3355/

during weekends than during weekdays (McMurray et al., 2016; Jago et al., 2014b). This evidence notwithstanding, the mechanisms of association between PA and ST levels in parents and their children have not been thoroughly investigated. For example, there has been little research on whether setting (e.g., home versus outside of home) moderates the association between parents' and children's PA and ST.

Considering that the Physical Activity Guidelines for Americans Midcourse Report (Physical Activity Guidelines for Americans Midcourse Report Subcommittee of the President's Council on Fitness SaN, 2012) emphasized family-based interventions, the current research was designed to examine associations between parents' levels of PA and ST and PA and ST in their children. Since mothers tend to spend more time with their children than fathers, we focused on the PA and ST associations between mothers and their children.

The specific aims of this study were to: describe the associations between mothers' and their children's levels of moderate to vigorous physical activity (MVPA) and ST (aim 1), test those associations for: A main effect of mothers' and children's characteristics and attributes of the home environment - specifically, number of electronic devices child has access to and number of items in the home that can be used for PA (aim 2), and a moderating effect of child sex, child age, weekdays versus weekends, and the condition of both members of the dyad being at home together (aim 3). We hypothesized that there would be significant mother-child associations in MVPA and ST (Strong et al., 2005), that more PA equipment available at home would influence the associations (U.S. Department of Health and Human Services, 2008), and the associations would be stronger when both members of the dyad are the same gender, be stronger in younger children, and be stronger when both parent and child were both at home (Kann et al., 2016).

2. Methods

2.1. Study design and participants

The study design was cross-sectional and included data from the University of Michigan Healthy Families study, conducted from summer 2013 to summer 2015. Ninety-two mothers (primary caregivers) who have children aged 3 to 5.99 years [n = 40] or 10 to 12.99 years [n = 52] were included in the original study. Families who lived within 1 h driving distance from the University of Michigan in Ann Arbor, Michigan and who speak English at home “most of the time” were included for this study. Only families in which the parent participant (mother) lives in the home with child (for whom she is a legal guardian) were included. Mothers and children with barriers to “normal” physical movement were excluded. Additional inclusion criteria for the child participants were: a) living in one home at least 5 of 7 days of the week (i.e., there was not split custody between two parents); b) without any major medical problems, significant developmental delays, and/or significant dietary restrictions; c) not born prematurely (i.e., was at least 37 weeks gestational age at birth); and d) born in the state of Michigan. Once eligibility was determined, a visit to the family's home was scheduled. Our research team visited the participants' home and obtained informed consent from the mother and verbal (from younger children) or written (from older children) assent from children. Our final analytic sample was 55 mother-child dyads (i.e., 25 mothers with children aged 3–5.99 years and 30 mothers with children aged 10–12.99 years). This final sample size was 60% of the original sample size (n = 92) mainly due to dyads failing to have enough common days as described in the *activity data preparation section.* Our sensitivity analysis showed that there was no significant difference in demographics between the final and original samples. This study was approved by the Institutional Review Board of the University of Michigan.

2.2. Data collection

All data were obtained at participants' homes.

2.2.1. Physical activity assessment

Participants were given an Actigraph wGT3X (Actigraph, LLC, Fort Walton Beach, FL) to wear during all waking hours for a seven-day period. Participants received a short lesson (5–10 min) from the research staff on how to properly wear the Actigraphs. They were asked to fasten the Actigraph snugly to their waist, except when they slept, bathed, or went swimming. The monitor was removed at bedtime and put back on in the morning when the participants got out of bed. Additionally, the participants were asked to keep an activity log to record when the monitor was taken off for bathing, sleeping, etc. and to record the times when they were at home and when they were outside of the home. The main outcome variables of interest were: MVPA as a proportion of total time, and ST as a proportion of total time a) in total and b) while the participants were at home.

Age-specific movement count thresholds were determined based on Freedson's energy expenditure prediction equation for children (Freedson et al., 2005) and Trioano's energy equation for mothers (Troiano et al., 2008). The activity intensity was defined in counts per minute (cpm). We defined ST as activity levels below 100 cpm for both parents and children, excluding periods of non-wear (Matthews et al., 2008). Non-wear time (i.e., at least 60 min of consecutive zero activity) was excluded for both mothers and children and periods the monitor was taken off (as reported in the activity logs) were counted towards non-wear time. Epochs for both mothers' and children's Actigraphs were defined as 5 s.

2.2.2. Other variables

Demographics were collected by maternal report on child's sex, mother and child's age, race/ethnicity, maternal education level, and family income (based on income-to-needs ratio). Weight status was determined by body mass index (BMI) data which was calculated from a participant's height and weight. Height and weight were measured using a stadiometer (Seca 213, Seca) and weight in kilograms was measured using an electronic scale (Tanita WB-110A, Tanita). For mothers, BMI (kg/m^2) was calculated and categorized into three weight-status groups (underweight/normal-weight [$<$ 25]; overweight [$\geq$ 25 and $<$ 30]; and obese [$\geq$ 30]). For children, BMI z-score was calculated based on US Centers for Disease Control and Prevention sex- and age-specific growth charts: Underweight ($<$ 5th percentile), Normal weight ($\geq$ 5th and $<$ 85th percentile), overweight ($\geq$ 85th and $<$ 95th percentile), and obese ($\geq$ 95th percentile) (Kuczmarski et al., 2000).

Home environment variables were assessed using the Active Where? Parent-Child Survey I, which measures attributes of home, community, and school environments which have been shown to be correlated to children's diet, PA, and ST, such as whether there are fast food restaurants near the home, sum value of electronic devices and pieces of PA equipment available in the child's home, whether children were able to walk or bike to school, etc. (Joe et al., n.d.; Sherwood et al., 2013) Only the home environment measures from the Survey (i.e., 13 items for assessing numbers of electronic devices at home and 14 items for assessing number of pieces of PA equipment available in the child's home) were included in this study. Intra-class correlation ranged from 0.261 (“Digital TV recorders in home) to 0.944 (“TVs in home”) among the 13 “electronic devices at home” items, and from 0.527 (“swimming pool) to 0.828 (“bike”) among the 14 “pieces of PA equipment available in the child's home” items (Joe et al., n.d.).

2.3. Statistical analysis

2.3.1. Activity data preparation

Activity data were restricted to dates within 7 days of the start date as some participants ($n = 6$) collected data outside of the desired range due to miscommunication early in data collection. The data set was then restricted to dyads in which the parents and children both wore the monitors on at least three weekdays and one weekend day in common during that seven day period. Based on the activity log data on whether PA took place at home or outside of the home, an "away" variable was created for tracking each minute of activity for each participant that took place outside the home (i.e., 0 – at home; 1 – away from the home). This allowed for creation of a binary "both home" variable that indicated if both mother and child were active at home at the same time, or if at least one was away from the home.

The minute-by-minute data were then summarized to hour-by-hour. We limited the data to 08:00 am–08:59 pm as very little data existed outside of this range. If participants had data for at least 75% of the minutes in a given hour, the proportion of ST, and LPA and MVPA was calculated. If both participants were at home for at least 75% of the hour, the hour was considered to be both at home. We then created a day of the week variable and categorical weekend variable. For the purpose of this study, the proportion of time per hour in sedentary, LPA, and MVPA were calculated and we used proportion of sedentary, LPA, and MVPA to compare data between mothers and children.

2.3.2. Hypothesis testing

Formal hypothesis testing was conducted using R version 3.2.2 (R Core Team, 2015) with a mixed-effects modeling framework implemented within the nlme (Pinheiro et al., 2015) and lme4 (Bates et al., 2015) packages. Children's hourly MVPA and ST were modeled as separate outcomes. In each model, traditional dummy coding was used to account for any temporal effects (8 am was set as the reference category). These dummy-coded hour effects were treated as fixed at level-1 (hour level). Maternal hourly MVPA (for the child MVPA model) or ST (for child ST model) was entered as a time-varying covariate at level-1. Model testing was conducted to assess whether this effect was best modeled as a fixed (constant across mother-child pairs) or random (varies across mother-child pairs) effect. The following variables were examined for individual main effects as well as used as covariates in all models: child's sex, age, BMI z-score, mother's age, race/ethnicity, BMI, mother's highest education, family income to needs ratio, number of available electronic devices in the home, number of PA equipment pieces available at home, weekend vs weekday, and whether mother and child were both at home.

To establish whether activity associations differed by child's sex, child's age, weekday vs weekend, and whether both mother and child were at home, each of these variables was entered separately as an interaction with maternal MVPA or ST within these models. Also, a three-way interaction of weekday versus weekend, both at home versus not both at home, and maternal MVPA or ST was tested. All hypotheses were tested using 2-tailed tests.

3. Results

Characteristics of study participants are displayed in Table 1. 50.9% of the children were boys and the majority of the participants were White (76.4%) and non-Hispanic (96.4%). 10.9% of the children were overweight and 18.2% were obese. The mean age of the mothers was about 38 years old, and 20.0% were overweight and 32.7% were obese. Mothers participated in MVPA 5% of the time, and ST 72% of the time. Children participated in MVPA 12% of the time, and ST 61% of the total time.

Figs. 1–2 show mothers' and children's MVPA and ST across time of day. Plots were stratified by the children's age group and whether both mother and child were home or if at least one member of the dyad was away from home. The graphs show that children 3–5.99 years old have higher rates of MVPA and lower rates of ST than children 10–12.99 years old. Mothers' MVPA and children's MVPA were associated when they were at home together. Also, mothers' ST and children's ST were associated when they were at home together. There was little variance in hour-by-hour MVPA and ST when stratified by setting (when both were home and when at least one was away from home) and child's age group.

Table 1
Sample characteristics (mother-child dyads $n = 55$).

	Mother	Child
	Mean (SD) or n (%)[a]	
Child's sex		
Male		28 (50.9%)
Female		27 (49.1%)
Child's age		8. 22 (3.66)
3–5.99 years		25 (45.5%)
10–12.99 years		30 (54.5%)
Mother's age	37.83 (7.15)	
Race		
White	42 (76.4%)	42 (76.4%)
Other	13 (23.6%)	13 (23.6%)
Child's BMI (mean z-score)		0.19 (1.33)
Underweight or normal[b]		39 (70.9%)
Overweight		6 (10.9%)
Obese		10 (18.2%)
Mother's BMI	28.35 (8.51)	
Underweight or normal[c]	26 (47.2%)	
Overweight	11 (20.0%)	
Obese	18 (32.7%)	
Maternal education		
High school[d]	8 (14.5%)	
Some college	15 (27.3%)	
2 year college degree	9 (16.4%)	
4 year college degree or more	23 (41.8%)	
Income-to-needs ratio[e]	1.76 (1.13)	
Home environment variables		
# of electronic devices child has access to	14.49 (5.36)	
# of items in the home that can be used for physical activity	7.87 (2.55)	
Moderate-to-vigorous PA (proportion)		
MVPA overall	0.05 (0.03)	0.12 (0.06)
MVPA, weekday	0.05 (0.03)	0.12 (0.06)
MVPA, weekend	0.05 (0.03)	0.12 (0.07)
MVPA, both at home	0.04 (0.03)	0.12 (0.06)
MVPA, when at least one away from home	0.05 (0.03)	0.13 (0.06)
Sedentary time (proportion)		
ST, overall	0.72 (0.08)	0.61 (0.08)
ST, weekday	0.72 (0.08)	0.61 (0.08)
ST, weekend	0.72 (0.08)	0.62 (0.11)
ST, both at home	0.72 (0.10)	0.63 (0.09)
ST, when at least one away from home	0.71 (0.08)	0.60 (0.09)

[a] Numbers may not add up to total n due to missing data.
[b] Five children (9.1%) were classified as underweight.
[c] Two mothers (3.6%) were classified as underweight.
[d] One mother (1.8%) reported less than high school graduate.
[e] Income-to-needs ratio was calculated using the midpoint of reported income.

Table 2 shows associations between the mothers' and children's MVPA while controlling for covariates. There was a significant positive association between the mothers' and children's MVPA in the unadjusted model ($\beta = 0.296$, p-value < 0.0001). In the fully adjusted model, the association between the mother's MVPA and child's MVPA remained statistically significant and there was a statistically significant interaction with the both home variable ($p = 0.034$). We calculated the simple slopes between mother's and child's MVPA at each level of the both home variable to describe the nature of this interaction. The relation between mother's and child's MVPA was stronger when both were at home ($\beta = 0.365$) as compared to when one or both were not at home ($\beta = 0.216$). Children who were 10–12.99 years old had significantly lower MVPA time than children 3–5.99 years old ($\beta = -0.090$, p-value < 0.0001), and the children's proportion of MVPA each hour increased significantly with each additional piece of PA equipment in the home ($\beta = 0.006$, p-value $= 0.0212$). All other two- and three-way interaction terms were nonsignificant.

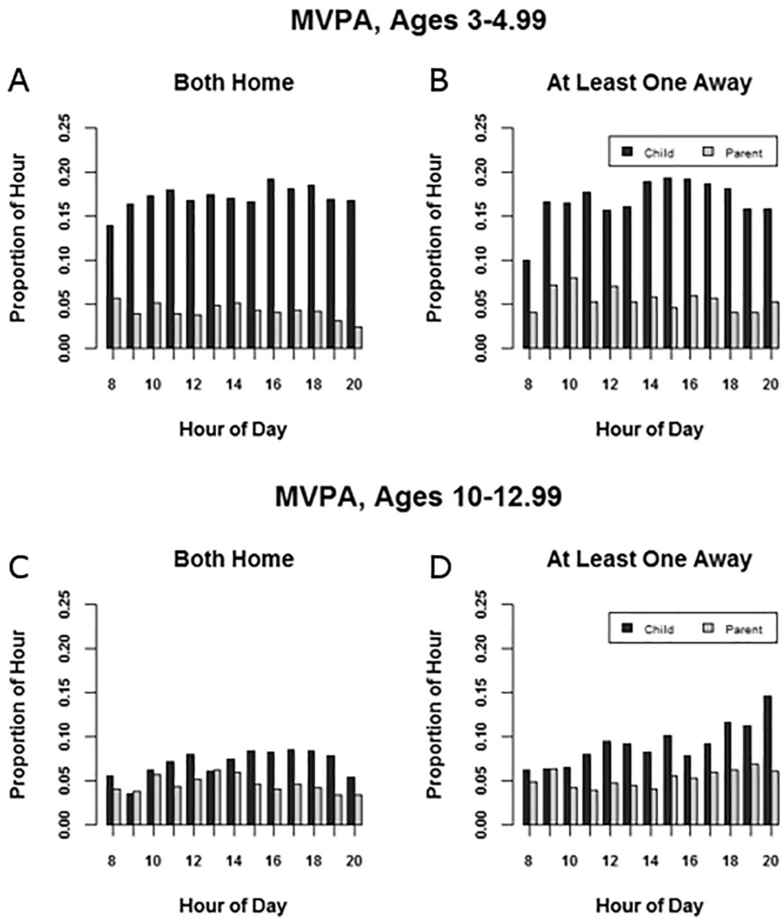

Fig. 1. Moderate-to-vigorous physical activity (MVPA) patterns, hour-by-hour, between mothers and their children, stratified by age and if both were home together.

Table 3 shows the associations between mother's and child's ST while controlling for covariates. There was a significant positive association between mother's ST and child's ST in the unadjusted model ($\beta = 0.179$, p-value < 0.0001). In the fully adjusted model, the association between mother's ST and child's ST remained statistically significant and there was a statistically significant interaction with the both home variable ($p < 0.001$). As above, we calculated the simple slopes between mother's and child's ST at each level of the both home variable to describe the nature of this interaction. The relation between mother's and child's ST was stronger when both were at home ($\beta = 0.255$) as compared to when one or both were not at home ($\beta = 0.117$). Children who were 10–12.99 years old had significantly higher ST than children 3–5.99 years old ($\beta = 0.074$, p-value $= 0.0004$). Mother's age showed a significant positive association with child ST in the fully adjusted model. Child BMI was also significantly associated with child ST in the adjusted model. However, child BMI and child ST were not significantly related in a completely unadjusted model suggesting that the significant result in the adjusted model may be due to a suppressor effect. For this reason, we do not interpret this effect further. All other two- and three-way interaction terms were nonsignificant.

4. Discussion

This study demonstrates a positive mother-child associations in levels of MVPA and ST for mothers and their children living in the same household. These findings are well-aligned with some previous research findings (Jago et al., 2010; Hesketh et al., 2014; Ruiz et al., 2011; Jago et al., 2014a; Fuemmeler et al., 2011; McMurray et al., 2016; Garriguet et al., 2017). A unique finding of this study is that the mother-child association for MVPA and ST was approximately two times stronger when both mother and child were at home together in comparison to when one of them was away from home (more specifically, 1.7 times stronger for MVPA and 2.2 times stronger for ST). Taken as a whole, our study supports the rationale for, and importance of, developing home-based interventions to increase PA and decrease ST across family members.

There are a number of benefits that can be realized through home-based interventions. They can be cost effective in focusing on changing mothers' and children's behaviors in a single intervention, as opposed to through separate interventions. Home-based interventions might provide parents a valuable opportunity for quality time with their children and might have an added benefit of strengthening the association between mothers' and children's MVPA/ST by reinforcing parents' influence as physically active role models. And finally, home-based interventions might enhance mothers' MVPA and/or reduce mothers' ST by encouraging them to model PA/sedentary behaviors for their children. Future home-based studies that examine the variety of benefits of particular types of PA interventions will be instructive for tailoring programs to take advantage of family and individual characteristics and preferences. Electronic real-time data capture strategies such as Ecological Momentary Assessment (EMA) might be helpful in such endeavors (Dunton et al., 2012).

Our findings are also in line with previous studies which show that characteristics of the physical home environment are associated with children's MVPA and ST levels (Lau et al., 2015). We show that the proportion of MVPA in children increased significantly with each additional piece of PA equipment reported in the household. Continued research will help maximize how to leverage home physical environment factors for enhancing PA and reducing ST through home-based

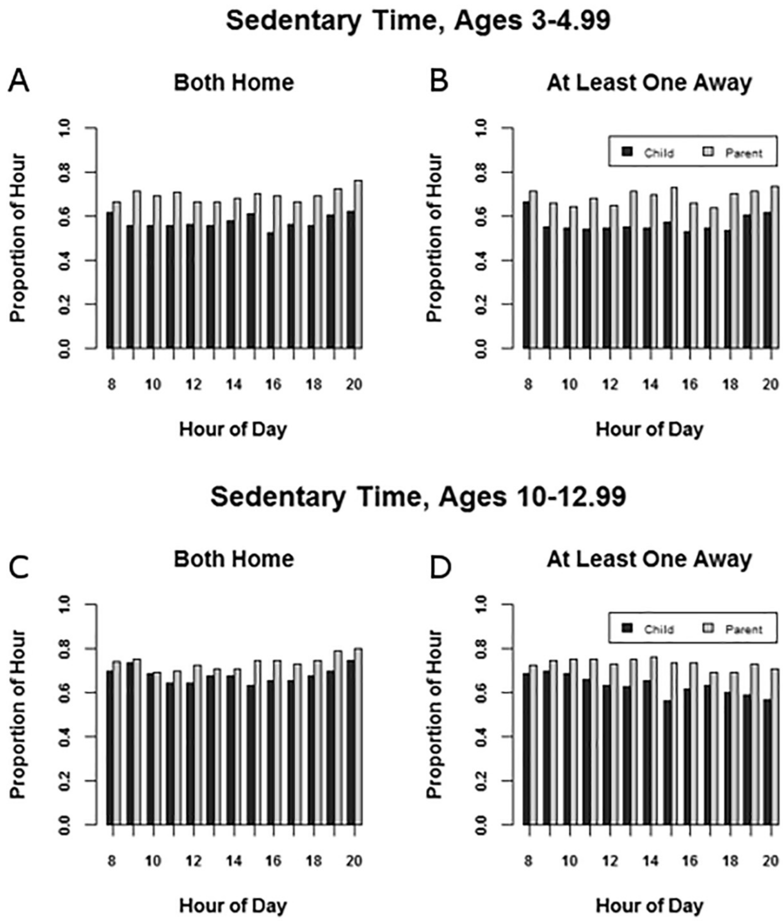

Fig. 2. Sedentary time patterns, hour-by-hour, between mothers and their children, stratified by age and if both were home together.

interventions. Such research could be expanded to assess the influence of home social environment as well (parenting behaviors, restrictions on TV time, etc.).

The current study found that children who were older had significantly lower MVPA and higher ST compared to younger children, as has been reported in previous studies (Kann et al., 2016; Janssen et al., 2016; Pearson et al., 2017; Dunton et al., 2012). However, we did not find that children's age moderated the association between maternal MVPA/ST and children's MVPA/ST. This suggests that parent-child interventions initiated when children are young could have a lasting effect of mitigating the known decline in MVPA and increase ST as children grow older (Dumith et al., 2011; Bradley et al., 2011; Gortmaker et al., 2012). Additionally, if home-based family interventions do increase mothers' MVPA by encouraging them to role model

Table 2
Associations between child and maternal MVPA time controlling for Covariates.

Variables	Unadjusted	Adjusted	Fully adjusted (including interaction)
Mother's MVPA	0.296 (0.154, 0.445) **	0.266 (0.122, 0.411)**	0.216 (0.067, 0.365)**
Female vs. male child	–	− 0.004 (− 0.026, 0.017)	− 0.004 (− 0.025, 0.018)
10–12.99 vs. 3–5.99 years	–	− 0.090 (− 0.113, − 0.066)**	− 0.090 (− 0.114, − 0.066)**
Child's BMIZ		0.005 (− 0.003, 0.013)	0.005 (− 0.003, 0.013)
Mother's BMI	–	0.000 (− 0.001, 0.002)	0.000 (− 0.001, 0.002)
Mother's age	–	− 0.001 (− 0.002, 0.001)	− 0.001 (− 0.002, 0.001)
Mother's education			
Some college	–	− 0.036 (− 0.078, 0.006)	− 0.037 (− 0.079, 0.005)
2 year college degree	–	− 0.015 (− 0.057, 0.028)	− 0.015 (− 0.058, 0.027)
≥ 4 year college degree	–	− 0.006 (− 0.053, 0.042)	− 0.007 (− 0.055, 0.041)
Mother non-white vs. white	–	0.025 (− 0.001, 0.051)	0.026 (0.000, 0.052)
Income to needs ratio	–	0.002 (− 0.010, 0.014)	0.002 (− 0.010, 0.014)
Number of electronic devices	–	0.002 (0.000, 0.004)	0.002 (0.000, 0.004)
Number of PA equipment available	–	0.006 (0.001, 0.011)*	0.006 (0.001, 0.011)*
Weekend vs. weekday	–	− 0.008 (− 0.016, 0.000)	− 0.008 (− 0.016, 0.000)
Both home vs. at least one away from home	–	− 0.023 (− 0.020, − 0.005)**	− 0.019 (− 0.029, − 0.009)**
Mother's MVPA/Both home interaction	–		0.149 (0.012, 0.286)*

Note: All models are adjusted for hour by including a set of orthogonal dummy variables with 8:00 am as the reference category (not shown). Unadjusted model was ran using lmer() from the lme4 package in R. All other models were ran using lme() from the nlme package in R.
* p-value < 0.05.
** p-value < 0.001.

Table 3
Associations between child and maternal sedentary time controlling for covariates.

Variables	Unadjusted	Adjusted	Fully adjusted (including interaction)
Mother's sedentary	0.179 (0.124, 0.234)**	0.176 (0.119, 0.232)**	0.117 (0.050, 0.183)**
Female vs. male child	–	0.005 (− 0.030, 0.040)	0.004 (− 0.031, 0.038)
10–12.99 vs. 3–5.99 years	–	0.074 (0.035, 0.112)**	0.074 (0.035, 0.112)*
Child's BMIZ	–	− 0.016 (− 0.029, − 0.003)*	− 0.016 (− 0.029, − 0.003)*
Mother's BMI	–	− 0.001 (− 0.004, 0.001)	− 0.002 (− 0.004, 0.001)
Mother's age	–	0.003 (0.000, 0.005)*	0.003 (0.000, 0.006)*
Mother's education			
Some college	–	0.059 (− 0.010, 0.128)	0.061 (− 0.008, 0.130)
2 year college degree	–	0.007 (− 0.063, 0.077)	0.008 (− 0.026, 0.077)
≥ 4 year college degree	–	0.012 (− 0.066, 0.090)	0.014 (− 0.064, 0.092)
Mother non-white vs. white	–	0.017 (− 0.025, 0.060)	0.017 (− 0.026, 0.059)
Income to needs ratio	–	− 0.014 (− 0.034, 0.005)	− 0.014 (− 0.033, 0.006)
Number of electronic devices	–	− 0.004 (− 0.007, 0.000)*	− 0.003 (− 0.006, 0.000)
Number of PA equipment available	–	− 0.000 (− 0.009, 0.008)	− 0.000 (− 0.009, 0.008)
Weekend vs. weekday	–	0.011 (− 0.004, 0.025)	0.009 (− 0.005, 0.024)
Both home vs. at least one away from home	–	0.031 (0.018, 0.045)**	− 0.066 (− 0.123, − 0.009)*
Mother's sedentary/Both home interaction	–	–	0.138 (0.059, 0.217)**

Note: All models are adjusted for hour by including a set of orthogonal dummy variables with 8:00 am as the reference category (not shown).
* p-value $<$ 0.05.
** p-value $<$ 0.001.

positive PA behaviors for their children, they may also help mitigate age-related declines in MVPA we have seen in adults (Camhi et al., 2011; Jones et al., 2016).

4.1. Limitations

Several limitations need to be taken into consideration. First, this is a cross-sectional study and as such, causality cannot be assumed. Second, parents included in this study were mothers, which could limit the generalizability of the findings. However, maternal modeling of PA has been reported to have a stronger association with PA in boys *and* girls compared with paternal modeling (Schoeppe et al., 2017). Third, although accelerometers provide useful information about PA and ST, they do not provide any contextual information about *types* of activities. Such information would be useful for designing future interventions. Fourth, our sample had a relatively high proportion of whites (76%), potentially limiting the generalizability. Fifth, due to the limited statistical power of our current study (55 parent-child dyads) there may additional be 2- or 3- way interaction effects than those we found. Lastly, other potential parental influences that have been found to significantly affect parent-child PA and ST associations (such as parental support, parenting style, and PA levels of the other parent and/or other family members) were not accounted for in the current study.

5. Conclusions

Our findings add to our current understanding of the relationship between mothers' and children's levels of MVPA and ST. An association was found, and it was much stronger when both mothers and children were both at home together than when one or both were not at home. These findings may improve efforts to develop home-based family intervention strategies for increasing PA and decreasing ST.

Funding sources

Funding for the Healthy Families Project was provided by the University of Michigan Momentum Center (www.momentumcenter.org).

References

Bates, D., Maechler, M., Bolker, B., Walker, S., 2015. Fitting linear mixed-effects models using lme4. J. Stat. Softw. 67 (1), 1–48.
Bradley, R.H., McRitchie, S., Houts, R.M., Nader, P., O'Brien, M., 2011. Parenting and the decline of physical activity from age 9 to 15. Int. J. Behav. Nutr. Phys. Act. 8, 33.
Camhi, S.M., Sisson, S.B., Johnson, W.D., Katzmarzyk, P.T., Tudor-Locke, C., 2011. Accelerometer-determined lifestyle activities in US adults. J. Phys. Act. Health 8 (3), 382–389.
Chung, A.E., Skinner, A.C., Steiner, M.J., Perrin, E.M., 2012. Physical activity and BMI in a nationally representative sample of children and adolescents. Clin. Pediatr. 51 (2), 122–129 (Phila).
Dumith, S.C., Gigante, D.P., Domingues, M.R., Kohl 3rd, H.W., 2011. Physical activity change during adolescence: a systematic review and a pooled analysis. Int. J. Epidemiol. 40 (3), 685–698.
Dunton, G.F., Liao, Y., Almanza, E., et al., 2012. Joint physical activity and sedentary behavior in parent-child pairs. Med. Sci. Sports Exerc. 44 (8), 1473–1480.
Freedson, P., Pober, D., Janz, K.F., 2005. Calibration of accelerometer output for children. Med. Sci. Sports Exerc. 37 (11 Suppl), S523–530.
Fuemmeler, B.F., Anderson, C.B., Masse, L.C., 2011. Parent-child relationship of directly measured physical activity. Int. J. Behav. Nutr. Phys. Act. 8, 17.
Garriguet, D., Colley, R., Bushnik, T., 2017. Parent-child association in physical activity and sedentary behaviour. Health Rep. 28 (6), 3–11.
Gortmaker, S.L., Lee, R., Cradock, A.L., Sobol, A.M., Duncan, D.T., Wang, Y.C., 2012. Disparities in youth physical activity in the United States: 2003-2006. Med. Sci. Sports Exerc. 44 (5), 888–893.
Hesketh, K.R., Goodfellow, L., Ekelund, U., et al., 2014. Activity levels in mothers and their preschool children. Pediatrics 133 (4), e973–e980.
Jago, R., Fox, K.R., Page, A.S., Brockman, R., Thompson, J.L., 2010. Parent and child physical activity and sedentary time: do active parents foster active children? BMC Public Health 10, 194.
Jago, R., Sebire, S., Wood, L., et al., 2014a. Associations between objectively assessed child and parental physical activity: a cross-sectional study of families with 5–6 year old children. BMC Public Health 14, 655.
Jago, R., Thompson, J.L., Sebire, S.J., et al., 2014b. Cross-sectional associations between the screen-time of parents and young children: differences by parent and child gender and day of the week. Int. J. Behav. Nutr. Phys. Act. 11, 54.
Janssen, X., Mann, K.D., Basterfield, L., et al., 2016. Development of sedentary behavior across childhood and adolescence: longitudinal analysis of the Gateshead millennium study. Int. J. Behav. Nutr. Phys. Act. 13, 88.
Joe, L.Carlson, J.Sallis, J. Active Where? Individual Item Reliability Statistics Parent/Child Survey. http://www.drjamessallis.sdsu.edu/Documents/AW_item_reliability_ParentChild.pdf.
Jones, S.A., Wen, F., Herring, A.H., Evenson, K.R., 2016. Correlates of US adult physical activity and sedentary behavior patterns. J. Sci. Med. Sport 19 (12), 1020–1027.
Kann, L., McManus, T., Harris, W.A., et al., 2016. Youth risk behavior surveillance - United States, 2015. MMWR Surveill. Summ. 65 (6), 1–174.
Kuczmarski, R.J., Ogden, C.L., Guo, S.S., et al., 2000. CDC growth charts for the United States: methods and development. Vital Health Stat. *11* (2002(246)), 1–190.
Lau, E.Y., Barr-Anderson, D.J., Dowda, M., Forthofer, M., Saunders, R.P., Pate, R.R., 2015. Associations between home environment and after-school physical activity and sedentary time among 6th grade children. Pediatr. Exerc. Sci. 27 (2), 226–233.
Matthews, C.E., Chen, K.Y., Freedson, P.S., et al., 2008. Amount of time spent in sedentary behaviors in the United States, 2003–2004. Am. J. Epidemiol. 167 (7), 875–881.
McMurray, R.G., Berry, D.C., Schwartz, T.A., et al., 2016. Relationships of physical activity and sedentary time in obese parent-child dyads: a cross-sectional study. BMC Public Health 16, 124.
Pearson, N., Haycraft, E., Johnston, J.P., Atkin, A.J., 2017. Sedentary behaviour across the primary-secondary school transition: a systematic review. Prev. Med. 94, 40–47.
Physical Activity Guidelines for Americans Midcourse Report Subcommittee of the President's Council on Fitness SaN, 2012Physical Activity Guidelines for Americans

Midcourse Report. Physical Activity Guidelines for Americans Midcourse Report: Strategies to Increase Physical Activity among Youth. U.S. Department of Health and Human Services, Washington, DC.

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., R Core Team. _nlme: Linear and Nonlinear Mixed Effects Models_, 2015. R package version 3.1–121. http://CRAN.R-project.org/package=nlme.

R Core Team, 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Ruiz, R., Gesell, S.B., Buchowski, M.S., Lambert, W., Barkin, S.L., 2011. The relationship between hispanic parents and their preschool-aged children's physical activity. Pediatrics 127 (5), 888–895.

Saunders, T.J., 2014. The health impact of sedentary behaviour in children and youth. Appl. Physiol. Nutr. Metab. = Physiol. Appl. Nutr. Metab. 39 (3), 402.

Schoeppe, S., Vandelanotte, C., Bere, E., et al., 2017. The influence of parental modelling on children's physical activity and screen time: does it differ by gender? Eur. J. Pub. Health 27 (1), 152–157.

Sherwood, N.E., Levy, R.L., Langer, S.L., et al., 2013. Healthy homes/healthy kids: a randomized trial of a pediatric primary care-based obesity prevention intervention for at-risk 5–10 year olds. Contemp. Clin. Trials 36 (1), 228–243.

Song, M., Carroll, D.D., Fulton, J.E., 2013. Meeting the 2008 physical activity guidelines for Americans among U.S. youth. Am. J. Prev. Med. 44 (3), 216–222.

Strong, W.B., Malina, R.M., Blimkie, C.J., et al., 2005. Evidence based physical activity for school-age youth. J. Pediatr. 146 (6), 732–737.

Tremblay, M.S., LeBlanc, A.G., Kho, M.E., et al., 2011. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. Int. J. Behav. Nutr. Phys. Act. 8, 98.

Troiano, R.P., Berrigan, D., Dodd, K.W., Masse, L.C., Tilert, T., McDowell, M., 2008. Physical activity in the United States measured by accelerometer. Med. Sci. Sports Exerc. 40 (1), 181–188.

Trost, S.G., Sirard, J.R., Dowda, M., Pfeiffer, K.A., Pate, R.R., 2003. Physical activity in overweight and nonoverweight preschool children. Int. J. Obes. Relat. Metab. Disord. 27 (7), 834–839.

U.S. Department of Health and Human Services, 2008. Physical Activity Guidelines for Americans. US Department of Health and Human Services, Washington, DC, pp. 2008.