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Parental Influence on Child Change in Physical Activity during a Family-Based Intervention for Child Weight Gain Prevention

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Abstract

Background—This study examined the association between parent and child change in physical activity during a family-based intervention for child weight gain prevention.

Methods—Daily step counts were recorded for parents and children in 83 families given a goal to increase activity by 2000 steps per day above baseline. Linear mixed effects models were utilized to predict child change in daily step counts from parental change in step counts.

Results—Both maternal ($p < .0001$) and paternal ($p < .0001$) change in step counts for the current day strongly predicted child change in step counts for that day. On average, a child took an additional 2117.6 steps above baseline on days his or her mother met her goal versus 1175.2 additional steps when the mother did not meet her goal. The respective values were 1598.0 versus 1123.1 steps for fathers. Day of week moderated the maternal effect ($p = 0.0019$), with a larger impact on Saturday and Sunday compared to weekdays. A similar but non-significant pattern was observed for fathers.

Conclusions—Encouraging parents to increase physical activity, particularly on weekends, may be a highly effective way to leverage parental involvement in interventions to increase children's physical activity.

Keywords

pediatric overweight; parent-child associations; daily step counts

Background

The prevalence of overweight among children in the United States has continued to rise since the 1960s.¹ In 2003–2004, 33.6% of children and adolescents in the US had a BMI for

age at or above the sex-specific 85th percentile,² which is considered overweight or obese.³ Family-based behavioral interventions are an effective approach for treating pediatric overweight, with positive outcomes demonstrated for time periods up to ten years following completion of the intervention.^{4,5} Several reviews of treatment for pediatric overweight have concluded that family-based behavioral treatments are a successful intervention format for pediatric obesity.⁶⁻⁸ These interventions focus on a variety of factors, including parent and child change in eating and activity levels.^{9,10} As such, one possible benefit of including parents in interventions is the influence of parent behavior change on child behavior change. Change in physical activity is particularly important because low levels of physical activity are a risk factor for pediatric overweight.¹¹⁻¹⁴

The vast majority of research focusing on the relation between parent and child activity levels consists of cross-sectional observational studies. These studies consistently find that parent's level of physical activity is associated with children's level of physical activity.¹⁵⁻²⁸ One prospective observational study found that mother's physical activity level (measured when children were in 5th grade) was predictive of girls' vigorous physical activity in 6th grade.²⁹ There have been inconsistent findings regarding whether gender-specific influence (i.e., mothers with daughters, fathers with sons) is stronger than cross-gender influence (i.e., mothers with sons, fathers with daughters). Several studies provide support for gender-specific influence,^{15,19,29} while other studies provide support for cross-gender influence.^{16,30}

Observational studies consistently demonstrate an association between parent and child level of physical activity. Research has not yet investigated the association between parent and child change in physical activity in family-based interventions that aim to increase physical activity. The purpose of this study was to test whether parent baseline physical activity and change in physical activity are significant predictors of child change in physical activity during a family-based intervention for child weight gain prevention. Daily step counts for parents and children were recorded throughout the intervention; as such, it was possible to test the effect of current day change in activity as well as lags in the effect of change in activity (for example, whether parents' prior seven days change in activity is predictive of children's change in physical activity). The secondary aim of this study was to explore potential moderators of the influence of parent change in physical activity, including gender and day of the week.

Methods

Study Overview

This family-based intervention was based on the small-changes approach promoted by the America on the Move initiative, which targets small changes in physical activity and diet. The intervention was designed to prevent excessive weight gain in children between the ages of 7 and 14 who were overweight or obese¹⁰ (defined as having a BMI ≥ 85th percentile for gender and age³). Families were randomly assigned to either the America on the Move group or a self-monitoring control group. Families in the control group were not utilized in the current analyses because they were not asked to change their physical activity level. One hundred families were randomized to the America on the Move group. Families in which the primary caregiver was not a parent (e.g., the caregiver who participated in the intervention was a grandparent or aunt) were excluded from the current analyses, leaving a total of 83 families for analysis. The primary targets of the intervention were the 100 children in these 83 families within the given age range who were classified as overweight or obese. Other children in the family not meeting age or BMI criteria were encouraged to participate with the family but were not targeted during the intervention, and therefore are not included in these analyses. Sixty-eight families had 1 target child participate in the intervention, 13

families had 2 target children, and 2 families had 3 target children. All 83 families had a mother who participated in the study and 34 families had a father who also participated in the study.

The study was approved by the Colorado Multiple Institutional Review Board of the University of Colorado at Denver and Health Sciences Center. Written informed consent and assent were obtained from parents and children, respectively, and parental consent was obtained for all minors who participated in the study. Participants were recruited through community organizations, health organizations, schools, and pediatrician offices.

After establishing baseline level of physical activity, children and parents in the intervention group were instructed to increase their physical activity level by walking an additional 2000 steps per day above their baseline level for the duration of the intervention. All participants in the intervention group were encouraged to set individual goals and family goals for participating in physical activity. A more detailed description of the intervention is provided by Rodearmel et al.¹⁰

Measures

Physical activity was measured by the number of steps taken per day by each study participant. All participants were given electronic pedometers (Accusplit AE120, San Jose, CA) and were thoroughly instructed in the use of the pedometers. This type of pedometer is reliable and valid³¹ and is often used in research.³² At the study enrollment meeting, all participants were given a binder that included a log for recording daily step counts. All participants were also given reminders (stickers for bathroom mirrors and refrigerator magnets) to record their daily step counts. Participants were instructed to wear their pedometers all day, every day, and to record their number of steps each night just before going to bed.

During the 2-week baseline period, participants were instructed to maintain their usual activity and record their number of steps each day. All participants recorded their steps for at least 10 days during the baseline period. After establishing an average number of steps per day for the baseline period, children and parents in the intervention group were instructed to walk an additional 2000 steps per day above their baseline level for the duration of the intervention. Each participant was instructed to record their number of steps each day throughout the first 18 weeks of the intervention.

Data Analysis

Data were analyzed using SAS/STAT version 9.1.3 (SAS Institute Inc, Cary, NC). Baseline characteristics were summarized using means and standard deviations for continuous variables and number and percentage of participants for categorical variables. Linear mixed effects models (PROC MIXED) were utilized for both primary and secondary analyses to predict daily change in step counts for children from changes in parental physical activity and covariates. Change in physical activity was calculated as each day's step count during the intervention minus the baseline step count. Change in activity was the focus of analysis because the intervention focused on changing physical activity in children and parents. Initial analyses examined change in parental physical activity as a continuous predictor variable. Additional analyses categorized parental physical activity according to whether the parent met his or her goal of increasing step counts by 2000 or more above baseline. For all analyses, significance tests were two-sided with a significance level of .05.

Linear mixed effects models account for the covariance structure within children and within families and also permits inclusion of target children with partially missing outcome data, including intermittent missing steps counts as well as missing data due to families dropping

out of the study. On average, each child recorded their step count on 96.4 days ($SD = 22.6$), and the minimum number of days for which a child recorded steps was 31. Seventeen percent of children dropped out of the study before the end of the intervention. For these analyses, it was assumed that the dropout pattern was random.

The first objective was to examine whether parent baseline physical activity and change in physical activity were associated with child change in physical activity. We first compared several different measures of parental change in physical activity including mother and father: current day change in steps, prior day change in steps, average of the prior seven days change in steps, and cumulative average of all prior days change in steps. Mother and father baseline physical activity were also examined. A separate model was fit for each of these parental activity variables to determine which aspect of parental activity best predicted child current day change in physical activity.

The second objective was to explore potential moderators of the influence of parent change in physical activity on child change in physical activity. The following moderators were selected *a priori* to be tested: child gender, child age, day of week, and intervention week. Each of these four variables was tested as a potential moderator of both maternal and paternal change in physical activity. In addition, the potential three-way interaction among maternal change in physical activity, target age, and target gender was tested. This three-way interaction was also tested for paternal change in physical activity. A backwards elimination procedure was used until only interactions that were statistically significant at $p < .05$ were included in the model.

All models (for both primary and secondary analyses) adjusted for the following covariates: child baseline step count, child gender, child age, child race/ethnicity, child baseline BMI-for-age z score, intervention week, day of week, and whether a father participated in the intervention. Child race/ethnicity, day of week, and intervention week were treated categorically. Not all families had a father participate in the intervention; therefore, an indicator variable was created for each target to signify whether the father participated in the intervention.

Both RANDOM and REPEATED statements were utilized to model the covariance structure for the repeated daily measurements of change in step counts within children as well as account for the correlation between children within the same family. All models included random subject and family effects with a variance components structure (TYPE=VC). The random family effect accounts for the correlation within the fifteen families with multiple children targeted in the intervention. Three residual covariance structures were examined: Toeplitz banded at 35 days (TYPE=TOEP35), as well as two structures that use Kronecker products to model the covariance within and between weeks (TYPE= UN@AR(1), and TYPE=UN@CS). Covariance structures based on Kronecker products are useful for modeling the covariance for two or more repeated factors in longitudinal data analysis.³³ The UN@CS structure estimates an unstructured covariance within the week and a compound symmetric structure from week to week. The compound symmetric structure estimates a single correlation between all Mondays throughout the study, a single correlation between all Tuesdays throughout the study, etc. for all seven days of the week. The UN@AR(1) structure also estimates an unstructured covariance within the week, but assumes that the correlation from week to week decays over time. Since all models included a random subject effect, this prevented covariance estimates of zero beyond the band length for the Toeplitz structure and prevented decay to zero for the UN@AR(1) model.³⁴ Covariance structures were compared using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). The UN@CS residual structure had the best fit for all models considered and thus was used for all reported analyses. Models were fit using

restricted maximum likelihood estimation, and denominator degrees of freedom were calculated using the Satterthwaite approximation.

Results

Descriptive information for participants is provided in Table 1. On average, children, mothers, and fathers all increased their physical activity during the intervention, although the average daily change in steps during the intervention for all three types of participants was less than the goal of 2000 additional steps per day. The baseline step count for children and mothers in families in which fathers participated in the study were compared to the baseline step count for children and mothers in families in which fathers did not participate. The baseline step count for children did not differ based on whether their father participated in the study. The baseline step count for mothers in families with a father who participated in the study was 1338 steps higher on average than mothers in families in which a father did not participate ($t_{81} = 2.43$, $p = .02$).

Table 2 provides results for models estimating the effect of parental baseline physical activity and various measures of parental change in physical activity on child change in physical activity. Based on 2 degree of freedom tests for overall effect of parental change in physical activity, parents' baseline physical activity does not predict child change in physical activity ($p = .46$), nor does parents' cumulative change in steps averaged across all prior days of the intervention ($p = .09$). Child change in physical activity is predicted by parents' change in steps on the current day ($p < .0001$), the prior day ($p = .02$), and averaged across the prior seven days ($p = .005$). Parents' current day change in steps is the most predictive of child change in physical activity.

Given that current day change in steps is the most predictive of child behavior, the four other models (baseline steps, prior day change in steps, prior seven days change in steps, and change in steps for all prior days) were calculated adjusting for maternal and paternal current day change in steps. Results are presented in Table 3. The only parental effect that remained significant when adjusting for parents' current day change in steps was prior seven days change in steps, which was significant at $p = .04$. Although prior seven days change in steps is still statistically significant, current day change in steps is by far the most highly significant effect of parental change in physical activity on child change in physical activity. As such, all further analyses focused on parent current day change in physical activity.

As shown in Table 2 (Model 5), for every additional 1000 steps that a mother takes in a day, her child takes an additional 196.0 steps ($p < .0001$). For every additional 1000 steps that a father takes in a day, his child takes an additional 82.4 steps ($p < .0001$). Several covariates in this model were also statistically significant. Child baseline physical activity was a predictor of child change in physical activity ($p < .0001$), with children who were more physically active at baseline taking fewer additional steps per day during the intervention. Day of week was also a predictor of child change in physical activity ($p < .0001$). Children were most active on Friday, followed by Thursday and then Saturday. Children were least active on Sunday. Child change in physical activity was also determined in part by intervention week ($p = .003$). Children's change in steps is lower in the initial weeks of the intervention. None of the other covariates predicted child change in physical activity at $p < .05$.

Next, potential moderators of the effect of maternal and paternal current day change in physical activity were tested by adding interaction terms. None of the variables tested moderated the effect of paternal change in physical activity at $p < .05$. The only variable tested that moderated the effect of maternal change in physical activity was day of week (p

= .0001). This model suggested that the effect of maternal change in physical activity was greatest on Saturday and Sunday (data not shown).

To further explore this interaction, maternal change in physical activity each day was treated as a categorical variable reflecting whether the mother met her goal of increasing her step count by 2000 steps above baseline. This variable was coded as 0 on days that the mother did not meet her goal and 1 on days that the mother did meet her goal. Day of week was still a significant moderator ($p = .0019$).

Averaging across all days of the week, children took an additional 2117.6 steps above their baseline steps on days that mothers met their goal, as compared to an additional 1175.2 steps above their baseline steps on days that mothers did not meet their goal. However, the significant interaction indicates that the effect of mothers meeting their goal differs by day of the week. The effect of mothers meeting their goal was greatest on Saturday and Sunday (see Figure 1). This is consistent with results of the model that treated maternal change in physical activity as a continuous variable. On both Saturday and Sunday, having a mother meet her goal was associated with children taking more than an additional 1000 steps compared to children of mothers who did not meet their goal. While the effect of having a mother meet her goal is greater on Saturday and Sunday than on weekdays, children of mothers who met their goal took significantly more steps than children of mothers who did not meet their goal every day of the week ($p < .001$ for all seven days of the week).

Although day of week did not moderate the effect of paternal current day change in physical activity ($p = .51$), results of this model are shown in Figure 2 for purposes of comparing the pattern for mothers and for fathers. The effect of fathers meeting their goal is greatest on Saturday and Sunday, which is consistent with results of the model for mothers. Averaging across all days of the week, children took an additional 1598.0 steps above their baseline steps on days that fathers met their goal, as compared to an additional 1123.1 steps above their baseline steps on days that fathers did not meet their goal.

Several sensitivity analyses were performed to assess the impact of various modeling options on results. The model for mother and father current day change in steps and the model with an interaction term for day of week with mother's current day change in steps (treated as a continuous variable) were tested in sensitivity analyses. These analyses involved testing models with only the 34 families in which fathers participated, models that randomly selected one child from each family, models using the TOEP(35) covariance structure with a random effect, and models using the UN@AR(1) covariance structure with a random effect. Substantive results did not change. In all models, both maternal and paternal current day change in steps was statistically significant at $p < .0001$. The interaction of maternal current day change in steps with day of week was statistically significant at $p < .01$ in all models except the model with only the 34 families in which fathers participated. The interaction term was not significant in this model. These results indicate that, by and large, results are not sensitive to the specific modeling techniques chosen for analyses.

Conclusions

This study demonstrates that parental change in physical activity is associated with child change in physical activity during a family-based intervention to prevent excessive weight gain in children. All participating family members were instructed to increase their physical activity level by walking an additional 2000 steps per day above their baseline level for the duration of the intervention. Parents' current day behavior had the most impact on their child's behavior. The effects of both maternal and paternal current day change in physical activity on child change in physical activity were highly statistically significant in a joint

model that tested the independent effect of each parent. This indicates that each parent has a significant effect independent of the effect of the other parent. However, mothers appear to have a larger effect than fathers. On average, children took an additional 2117.6 steps above their baseline steps on days that mothers met their goal, as compared to an additional 1598.0 steps on days that fathers met their goal.

The effect of maternal change in physical activity was moderated by day of week, with the largest effect on Saturday and Sunday. Day of week was not a statistically significant moderator of the effect of paternal change in physical activity, but the pattern was the same in that the largest impact of fathers was observed on Saturday and Sunday. These findings suggest that encouraging parents to increase their physical activity on weekends may be a highly effective way to leverage parental involvement in interventions to increase children's physical activity.

Intervention week did not moderate the effect of parents on children, which indicates that the effect of parental change in physical activity on child change in physical activity did not change significantly during the course of the intervention. Gender of the child did not moderate the effect of parental change on child activity for mothers or for fathers. As such, this study does not support prior studies that have found gender-specific influence^{15,19,29} and cross-gender influence^{16,30} of parents on children's physical activity, although the current study was not specifically powered to test such an effect. Age of the child also did not moderate the effect of either maternal or paternal current day change in physical activity. This is in contrast to a cross-sectional, non-intervention study of children in grades 4 through 12 which found that the association between parent and child physical activity levels is higher for younger children than for older children.²³ Given that the current study did not include children older than age 14, the difference in results could be due to the restricted age range of the current study. It is possible that as children progress through adolescence, they are less likely to be influenced by their parents' activity levels.

Results of this study should be interpreted in light of limitations of the study. These analyses are based on the intervention arm of a randomized study. The original study was not designed to investigate parent influence on child change in physical activity. As such, information about the extent to which parents and children participate in physical activities together was not available. Results suggest that parents and children participate in physical activities together; however, findings would be strengthened by measuring the extent to which parents and children participate in physical activities together each day of the week. A second limitation is that more than half of the families did not have a father participate in the intervention. Selection bias is possible, and in fact, the baseline step count for mothers was higher in families in which the father participated than in families in which the father did not participate. While families in which both mothers and fathers participate may differ in a variety of ways from families in which only mothers participate, sensitivity analyses suggest that estimates of the effect of maternal and paternal change in physical activity are consistent across the models tested. Finally, change in physical activity was a self-reported variable in this study and objective measures of physical activity were not used.

Strengths of this study include the fact that both parent and child reports of physical activity were utilized in analyses. Utilizing self-report of physical activity from multiple family members mitigates some concerns associated with the use of self-reported data: parents and children would have to coordinate with each other on a daily basis to jointly falsify step counts that would artificially create the observed association between parent change in physical activity and child change in physical activity. A second strength of this study is that the effect of both mothers and fathers was estimated, which allows for inferences about the effects of both parents on child change in physical activity. A further strength of this study is

that analyses were able to utilize a very detailed data set—daily step counts from multiple family members over a time period spanning more than four months—to model change in physical activity over the course of an intervention designed to prevent excessive weight gain in children.

The present study is important in that it is, to our knowledge, the first study to use daily measures of physical activity for parents and children to investigate the influence of parental change in physical activity on child change in physical activity during a family-based intervention. Results indicate that both maternal and paternal current day change in physical activity independently predict child change in physical activity. Day of week moderates the effect of maternal change in physical activity, with mothers having the most influence on Saturdays and Sundays. While not statistically significant, the pattern for fathers was the same—the largest impact of fathers was observed on Saturday and Sunday. These findings suggest that encouraging parents to increase their physical activity on weekends may be a highly effective way to leverage parental involvement in interventions to increase children's physical activity.

Parents and children may participate in physical activities together (such as going for walks), and parents may be more likely to participate in physical activities with their children on weekends than on weekdays. Future studies should include both mothers and fathers and should measure the extent to which parents and children participate in physical activities together. Research is needed to determine the extent to which the effect of parental change in physical activity on child change in physical activity is due to parents and children engaging in activities together and the extent to which other factors are influential, such as parents working with their children to set goals for physical activity for all members of the family on a given day. This information can be leveraged to incorporate parents into family-based interventions in an even more targeted way, with the goal of developing even more effective family-based interventions for pediatric obesity. Family-based interventions may be most effective if parents and children are encouraged to engage in physical activities together. Future research should also investigate the extent to which additional factors (such as socioeconomic status, parental employment status, and family structure) moderate the influence of parents on child change in physical activity.

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Figure 1. Effect of Mothers' Current Day change in Physical Activity by Day of the Week*

* Estimates from a linear mixed effects model

Figure 2. Effect of Fathers' Current Day Change in Physical Activity by Day of the Week*

* Estimates from a linear mixed effects model

Table 1
Characteristics of Participants

Measure	Children (n = 100) Mean (SD)	Mothers (n = 83) Mean (SD)	Fathers (n = 34) Mean (SD)
Age in years	11.06 (2.15)	42.97 (6.04)	45.65 (7.09)
Male gender, n (%)	47 (47%)	0 (0.0%)	34 (100%)
Race/ethnicity, n (%)			
Caucasian	56 (56%)	56 (68%)	30 (88%)
African American	15 (15%)	9 (11%)	3 (9%)
Hispanic	18 (18%)	11 (13%)	1 (3%)
Other	11 (11%)	7 (8%)	0 (0%)
Baseline BMI	24.85 (4.87)	30.79 (7.75)	31.15 (6.45)
Baseline BMI-for-age z score	1.71 (0.40)	--	--
Baseline step count	9122.34 (2709.05)	7255.52 (2540.57)	8328.32 (2575.17)
Average change per day in step count during intervention	1609.76 (1644.21)	1383.13 (1103.22)	825.63 (2001.52)
Percentage of days step goal met	53.54%	47.88%	43.52%

Table 2
Effect of Measures of Parental Physical Activity on Child Current Day Change in Physical Activity

Model*	Mothers		Fathers	
	Estimate (SE) [†]	p-value	Estimate (SE) [†]	p-value
Model 1				
Baseline Steps	81.4 (65.0)	0.21	10.8 (95.6)	0.91
Model 2				
Prior Day Change in Steps	36.4 (14.2)	0.01	11.9 (16.8)	0.48
Model 3				
Prior 7 Days Change in Steps	104.8 (31.9)	0.001	-19.7 (34.8)	0.57
Model 4				
All Prior Days Change in Steps	128.2 (58.3)	0.03	-18.4 (58.7)	0.75
Model 5				
Current Day Change in Steps	196.0 (14.0)	<0.0001	82.4 (16.9)	<0.0001

* Linear mixed effects models predicting child change in daily step counts from parental change in physical activity. All model also adjust for target baseline step count, target gender, target age, target race/ethnicity, target baseline BMI-for-age z score, intervention week, day of week, and whether a father participated in the intervention

[†] Increase in child's steps per 1000 step increase in mother's or father's physical activity

[‡] 2 degrees of freedom test for overall effect of parental change in physical activity on child change in physical activity

Table 3
Effect of Measures of Parental Physical Activity on Child Current Day Change in Physical Activity, Adjusting for Parent Current Day Change in Physical Activity

Model [*]	Mothers		Fathers	
	Estimate (SE) [†]	p-value	Estimate (SE) [†]	p-value
Model 1				
Baseline Steps	78.8 (63.0)	0.21	41.2 (93.0)	0.66
Current Day Change in Steps	196.0 (14.0)	< 0.0001	82.9 (17.0)	< 0.0001
Model 2				
Prior Day Change in Steps	26.4 (14.4)	0.07	2.7 (17.0)	0.87
Current Day Change in Steps	193.4 (14.4)	< 0.0001	87.3 (17.5)	< 0.0001
Model 3				
Prior 7 Days Change in Steps	59.5 (32.5)	0.07	-71.3 (36.1)	0.05
Current Day Change in Steps	194.0 (14.1)	< 0.0001	89.5 (17.3)	< 0.0001
Model 4				
All Prior Days Change in Steps	48.6 (58.8)	0.41	-73.7 (59.1)	0.21
Current Day Change in Steps	195.1 (14.1)	< 0.0001	85.2 (17.1)	< 0.0001

^{*} Linear mixed effects models predicting child change in daily step counts from parental change in physical activity. All models adjust for maternal and paternal current day change in steps and target baseline step count, target gender, target age, target race/ethnicity, target baseline BMI-for-age z score, intervention week, day of week, and whether a father participated in the intervention

[†] Increase in child's steps per 1000 step increase in mother's or father's physical activity

[‡] 2 degrees of freedom test for overall effect of parental change in physical activity on child change in physical activity