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ORIGINAL RESEARCH

The Relationship Between Maternal and Obese Children's Daily Physical Activity.

SHELBY J. FOOTE†1, ALEXANDRA VENEZIA†,1 DARBY J. WINKLER†1, KEITH R. LOSCHE‡2, and DANIELLE D. WADSWORTH‡1

[1]Exercise Adherence Laboratory, School of Kinesiology, Auburn University, Auburn, AL, USA; [2]Department of Health, Kinesiology and Recreation, University of Utah, Salt Lake City, UT, USA.

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 12(5): 1302-1314, 2019. This study examined the effects of maternal influence on child's daily physical activity. Participants consisted of eight families; parents (n = 9) and obese children (n = 10). Families were asked to attend exercise sessions at a university laboratory for 10 weeks. Daily physical activity was measured with a MovBand 3 which is a wrist worn accelerometer that records physical activity as moves. Linear mixed-effects models were used to predict daily physical activity over time and child physical activity as a function of parent physical activity on a day-to-day basis. Physical activity for all participants did not change significantly ($p > .05$) over the course of the intervention, however, there was a significant ($p = .001$) relationship between maternal and child physical activity showing for every step a mother took their child took 1.2 steps. On average, mothers achieved 2825.18 ± 1282.77 fewer moves than their children on a daily basis. Encouraging parents to engage in physical activity with their children may have a positive impact on their obese child's daily physical activity involvement.

KEY WORDS: Wearable technology, family influence, intervention

INTRODUCTION

Despite significant health initiatives, childhood obesity is a health concern for the United States (43). Childhood obesity has more than doubled in children and adolescents in the past 30 years, with more than one-third of U.S. children considered overweight or obese (33). Recent data from nationally representative samples shows a continued upward trend in childhood obesity rates (43). Childhood obesity is a multifaceted phenomenon that can have detrimental effects on lifetime health. However, change in obesity status or weight loss alone may not have the most beneficial impact on overall health. Incorporating more physical activity and structured exercise into interventions to promote an increase in childhood physical fitness, compared to a decrease in weight status, could encourage more positive psychological and physiological benefits than a weight loss intervention. For example, a study examining the differences between obese adults with high fitness levels (fitness assessed on maximal treadmill test) compared to obese individuals with low fitness levels found that the individuals with better fitness levels had lower risk (30 - 50%) of all-cause mortality, non-fatal and fatal heart disease, and cancer mortality than their lower fit, obese counterparts (32) An additional study examining obese adolescents (mean age = 14.5 years) found that higher cardiovascular fitness was associated with lower triglycerides, lower cholesterol and impaired fasting glucose after controlling for total body fat (27). According to the American College of Sports Medicine (2015), engaging in 60 minutes of physical activity on most days of the week aids in the growth and development of children, and is associated with psychological benefits for youth regardless of weight status (8, 14, 22). Although the benefits associated with regular physical activity for children are well documented (35) reports suggest that only 58% of children meet physical activity recommendations, with obese and overweight children typically participating in less physical activity than their normal weight counterparts (31,45). In addition, a decline in overall physical fitness has been documented in pediatric populations (42) and contributes to the childhood obesity epidemic (32). Establishing physical activity and fitness behavior early in life is key, because regular physical activity behavior and skills developed in childhood and early adolescence are likely to translate into adulthood (16).

Behavior change is a multidirectional process with multiple levels of influence, particularly for children. Parents and caregivers are often viewed as their child's primary gatekeepers (39), therefore, the child's physical activity could be dependent upon the regulatory capacity of their parents. Recent family-based intervention studies have suggested that when parents are more active, their children tend to be more active (18, 50). These findings were also consistent when looking at younger sedentary children (17) and active mothers (23). Previous research indicates that parents who are physically active model these behaviors to their children providing opportunity for children to mimic these behaviors. In a recent study, children's mothers had more influence on their physical activity levels compared to their fathers between the ages of 5 - 9 (25). This may be especially important for girls' physical activity behavior who are less likely to be active than boys (17, 10). In addition, active parents provide more support for their children to be physically active by taking an active role in facilitating physical activity behavior (18, 28, 29). However, there is a gap in the literature examining the relationship between obese children's daily physical activity and their mother's physical activity.

In addition to modeling behaviors, awareness of daily physical activity patterns can promote physical activity. Studies that incorporate the use of an activity tracker as a means of objectively measuring physical activity have shown positive physical activity and health outcomes (13, 6). Activity trackers provide the ability to easily self-monitor by providing immediate feedback and activity as an environmental cue (i.e. a reminder to be active; 48). Tudor-Locke, Meyers and Rodger (2001) also suggest the incorporation of progressive goal setting and refinement to encourage increases in physical activity. Furthermore, as technology has progressed, we are able to track physical activity on a daily basis over the course of the entire intervention versus a pre/post design.

Although the research examining parental influence on child physical activity for obese children appears promising, there is a gap in the literature as to how these interventions change daily physical activity overtime in a family-based intervention. Therefore, the purpose of this study was to examine 1) changes in daily physical activity among parents and obese children and 2) the effect of parents' physical activity on their child's physical activity during a family-based fitness program.

METHODS

Participants

Families were recruited from the community via flyers, email blasts, and social media. All families that had a least one child between the ages of 5 - 12 with a Body Mass Index (BMI) over the 85th percentile and at least one parent willing to participate, were invited to join the study. All participating parents reported participating in structured exercise no more than 1 day per week. This cohort consisted of eight families; nine parents (eight mothers and one father) and 10 children (six males and four females). All nine parents consented for their family and all 10 children assented to be in the study. Only two children reported participating in outside physical activities, swimming and baseball, during the time of the intervention. Ethical approval was obtained from the university's Human Research Ethics Committee prior to recruitment.

Protocol

This family-based fitness intervention consisted of sessions that met once per week (60 - 90 minutes) for 10 weeks. All sessions took place in two university laboratories. Orientation sessions prior to the intervention consisted of obtaining informed consent for the parent and child agreement, completion of the physical activity readiness questionnaire (PAR-Q) for adults (35) and a PAR-Q adapted for children (34), collecting demographic information from parents, height and weight assessments on both parent and children and a MOVABLE MOVband3 activity tracker orientation.

The intervention sessions were approximately 60 - 90 minutes in duration once per week and developed upon premises recommended in childhood obesity literature (30). These techniques included: targeting the child and parent for multiple behavior change techniques, targeting the child alone as well as targeting the parent and child together. Therefore, we utilized self-regulation skills associated with exercise adherence (21) including self-monitoring, time management, social (family) support, reinforcements and goal setting within the sessions with both the mother and the child (final 15 - 20 minutes) and allowed the mother and child to exercise separately (first 40 - 45 minutes). Parent sessions consisted of cardiovascular and resistance-training exercises that focused on teaching basic movements (i.e. squats, lunges, planks, overhead press) that were body weight movements or used minimal equipment. Parents were also trained on how these movements could be incorporated into their daily schedule. These exercise sessions were followed by short 6 - 10-minute education sessions, consisting of health implications of sedentary behavior, nutrition, goal setting, self-regulation techniques, time management, relapse prevention, social support, and reinforcements.

Child sessions were approximately 15 minutes in duration of structured lessons that focused on fitness education, motor skill development, and strategies for implementation outside of the intervention. These sessions included: how to be more active throughout your day, muscular strength-oriented lessons, cardiovascular oriented lessons and child-led lessons. Muscular strength lessons focused on learning how to do various body weight exercises (push-ups, squats, lunges, sit-ups) and what area of the body each exercise was targeting (arms, stomach, legs). Cardiovascular oriented lessons focused on learning about different ways such as running, quick step-ups, agility ladders, and jumping rope, to exercise their heart and lungs. Child-led lessons allowed children to design exercises that target different parts of the body and how they thought they could be more active throughout their day. Each 15-minute lesson was followed by approximately 25 - 30 minutes of free play.

For the final 15 - 20 minutes of each session, the family sat down together with a lead member of the research team to discuss self-regulation logs, set individual and family-based goals, discuss how to implement fitness activities at home and examine progress over the past week. Both mothers and their children were asked to self-monitor their daily physical activity by recording their moves from their MOVband3, and specific activities that they engaged in to obtain their moves on a self-regulation log sheet. Self-regulation logs were given in paper form during the participating family's weekly sessions. To promote self-monitoring and completion of self-regulation logs, research personnel reviewed the previous week's logs with each individual and helped set individual and family-based goals for the upcoming week. Individual goals were personalized and based on previous activity and future goals, whereas, family-based goals were created to promote accountability within the family. Recommendations for exercise and physical activity outside of the intervention were based on what had been learned in the exercise sessions and what resources the family had available. For example, if the lesson focused on muscular strength the researcher would ask the family to make a goal of how they could incorporate muscular strength activities into the week and what type of activities that would entail. For some families this may include a kick ball game that would have the family crab walk or lunge from base to base or a trip to the park to play on the play structures.

Physical activity tracking: Physical activity data was collected using the MOVABLE MOVband3 activity tracker (Dynamic Health Solutions, LLC, Houston, Texas). The MOVband3 utilizes tri-axial accelerometry and demographic information to estimate "moves" or physical activity during a 24-hour period. The MOVband3 has companion software that can estimate physical activity in 1-hour intervals. Approximately 12,000 moves are equivalent to 10,000 steps (i.e. 1.2 moves is equivalent to 1 step) (Dynamic Health Solutions, LLC, Houston, Texas). For adult's reliability for the Movband on a treadmill has been reported as $r = 0.92$, $p < 0.02$ and for free living PA as $r = 0.974$ (3). For children aged 6 - 12 laboratory criterion validity and reliability was reported as $r = 0.90$, $p < 0.002$ and free-living PA $r = 0.90$, $p < 0.005$ (42). Each participant's demographic information (height, weight, birth date, and sex) was used to program the activity tracker. Participating parents and children were given a MOVband3 during the week prior to the intervention and were instructed to wear the activity tracker on their wrist during the day;

taking the activity tracker off only for water-based activities. Previous research on activity tracker wear-compliance suggests that children are more compliant to wrist-worn compared to a hip-worn monitors due to comfort and feedback mechanisms (19, 39). Participants were instructed to continue wearing the activity tracker throughout the duration of the intervention.

Post-testing began 1 week following the cessation of the intervention and consisted of a final MOVband download. The preceding methodology is an abbreviated subset of this study's methods and procedures as it pertains directly to the physical activity component of the intervention. A detailed description of this intervention's procedures and methodology is published as a separate entity (20).

Statistical Analysis
Physical activity data were broken down into hourly segments. For example, 5:00am activity represented physical activity taking place between 5:00 - 5:59 a.m. Physical activity data were downloaded from the hours of 5:00 a.m. to 12:00 a.m. on the six days per week outside of their weekly session. If a participant had more than 3 consecutive hours of zero moves within their normal wake hours, their data for that time was treated as missing data. This parameter was based off of non-wear time detection in research grade accelerometers (7). Wake hours were determined by visual inspection of habitual activity on weekdays and weekend days, separately. For this particular analysis, we utilized the participants' daily moves.

Data analyses were conducted using R and R Studio using the dplyr, lme4, and lmerTest packages (4, 24, 38, 51). Linear mixed-effects models were used for both primary and secondary analyses to predict daily physical activity over time and child physical activity as a function of parent physical activity on a day-to-day basis. The change in physical activity and the relationship between maternal activity and child activity was the focus of this set of analyses. Due to the nested nature of the data, linear mixed-effects models were chosen to account for the variance of time nested within individuals and individuals nested within families. These two levels of between-subject factors are referred to as time and family status (i.e. whether a participant was a parent or child) within the statistical models. Mixed-effect regression was chosen over other techniques (e.g., RM ANOVA) as this method allows for participants with partially missing data and data being collected at different times. On average, each child was missing 29.4% and each parent was missing 20.4% of their daily moves for the 10-week, 60-day data collection. Based on information collected during the review of the self-regulation logs missing data was due to non-wear time.

To model changes in physical activity as a function of time and family status, a step-up procedure was used in which variables were added to successive models. All models started with predicting moves per day as function of the average number of moves for each participant (random intercepts, model 0). Then time was added as a predictor to see if moves per day changed as a function of time (random slopes, model 1). To test potential differences within a family, family status was added to see if there were significant differences between parents and children on average (model 2). Next, interaction family status and time were added to see if the rate of change in moves per day differed between parents and children (model 3).

To model the relationship between parent's physical activity and children's physical activity, a model was used that predicted children's daily moves as function of the average number of moves for each child (random intercepts, model 0). Given that maternal physical activity has been suggested to be a strong predictor of child physical activity (10, 23), child daily moves were plotted against parent daily moves for each family to evaluate how the relationship should be modeled. For this analysis, an equal data set was needed for each family and wanted to further investigate the relationships between maternal and child physical activity; therefore, for the one family that had both parents participate, only the mother's physical activity data was utilized. Upon visual inspection, on average it appeared that there was a positive linear relationship between children's daily moves and mother's daily moves. As such, a predictor of mother's daily moves (model 1) was added. Subsequently a random-effect of mother's daily moves (random slopes, model 2) was added, to determine if allowing different slopes for each child significantly improved the fit of the model. All models in both sets of analyses (moves a function of family status and the relationship between mother's and children's moves) were compared based on the Akaike Information Criterion (AIC) and the Wald Test of the change in deviance.

RESULTS

Descriptive information for participants is provided in Table 1. Nine children attended all sessions and one child missed one session due to illness. On average, children achieved 15794 ± 609.8 moves and parents achieved 13137 ± 109.7 moves at baseline. The participants' step equivalent would be approximately 13,161 steps for children and 10,947 steps for parents per day at baseline, suggesting that the participants were meeting step recommendations for both children (1) and adults (49) at the onset of the intervention. Physical activity did not change for the participants over the course of the intervention ($p > .05$).

Table 1. Descriptive Characteristics

Measure	Children (n = 10) Mean (*SD*)	Parents (n = 9) Mean (*SD*)
Age (yrs)	8.5 ± 1.78	38.6 ± 6.54
Gender, *n* *Male, Female*	6 (60%),4 (40%)	1 (11%), 8 (89%)
Race/ Ethnicity, *n* *Caucasian, African American*	8 (80%), 2 (20%)	8 (89%), 1(11%)
Parental Education, *n*		
High School	-	2 (23%)
Bachelor's	-	3 (33%)
Master's	-	3 (33%)
PhD	-	1 (11%)
Parental Work Status, *n*		
Part time	-	1 (11%)
Full Time	-	8 (89%)
Baseline BMI*	96.9 ± 1.87	33.1 ± 6.70

Baseline Moves	15794 ± 609.8	13137 ± 109.7
Baseline Approximate Steps**	13161 ± 507.5	10947 ± 90.8

*Baseline BMI for children is provided as a BMI percentile as outlined by the Centers for Disease Control and Prevention classification's age- and sex-specific BMI cutoff points for 'normal weight' (84th percentile and below), 'overweight' (85th to 94th percentile) and 'obese' (95th and above). **1.2 moves is equal to approximately 1 step

Table 2 provides results for models predicting daily physical activity over time. Comparing the different models for predicting daily physical activity, model 2 provided the lowest AIC and statistically significant decrease in deviance beyond model 1. As shown in Table 2, when adding in the effect of family status and controlling for time, this model was seen as the best-fitting and most significant predictor of daily physical activity. Model 2 suggested that, on average, participants decreased their physical activity by 11.11 ± 14.0 moves per day. In addition, there was not a significant difference ($p > .05$) between daily child moves and daily parent moves. Parents were getting on average 2825.18 ± 1282.77 fewer moves than their children on a daily basis (Table 3). This model suggests that parents were getting fewer moves per day than their children; however, the rate at which their physical activity changed over the course of the intervention was not different from their children's.

Table 2. Daily Physical Activity Over Time.

Model	AIC	Wald Test
Model 0		
Baseline	17204	
Model 1		
Effect of time	17196	$\chi2(3) = 13.79$, $p = 0.003$
Model 2*		
Effect of family status controlling for time	17194	$\chi2(1) = 3.86$, $p = 0.049$
Model 3		
Interaction of family status over time	17194	$\chi2(1) = 2.29$, $p = 0.129$

*Best fitting model

Table 3. Child Physical Activity as a function of Maternal Physical Activity.

Model	AIC	Wald Test
Model 0		
Child Baseline	2357.7	
Model 1*		
Fixed Effect of Maternal Activity	2349.1	$\chi2(1) = 10.63$, $p = 0.001$
Model 2		
Random Effect of Maternal Activity	2350.1	$\chi2(1) = 3.01$, $p = 0.222$

*Best fitting model

Table 4. Parameters of Best Fitting Models.

Model	Estimate moves	SE	95% Confidence Interval
Daily Physical Activity Over Time (M2)			
Child Baseline	14604.47	680.01	± 1360.02*
Change over Time	-11.11	14.0	± 28.00
Parental Differences	-2825.18	1282.77	± 2565.54*
Child Activity as a Function of Maternal Activity (M1)			
Child Average$_a$	15806.73	524.85	± 1049.7*

Maternal Influence[b]	191.82	57.26	± 114.52*

[a]Child average moves when mothers achieve average moves; [b]Based on 1,000 increment change in maternal moves; *A confidence interval that does not contain zero (i.e. $p < .05$)

When comparing the different models for examining the relationship between maternal physical activity and child physical activity, model 1 provided the lowest AIC (Table 3). After adding the predictor of maternal physical activity (Model 1) and mean centering maternal physical activity, this model suggested that when mothers were achieving their average number of moves, children were getting on average 15806.73 ± 524.85 moves per day. When examining the relationship between mothers' physical activity and their children's activity, our results indicated that for every 1,000 moves a mother achieved above her average, her child achieved an additional 191.8 ± 57.3 moves per day ($p = .001$) (Table 4), indicating a significant relationship between maternal physical activity and their children's physical activity on a day-to-day basis.

DISCUSSION

This study examined daily changes in physical activity over the course of a family fitness intervention for obese children and their families. In addition, we aimed to determine the relationship between parental physical activity and child physical activity throughout the intervention. Our results suggest that overall physical activity did not change for the participants over the course of the intervention ($p > .05$). However, baseline physical activity suggested that all of the participants were meeting step recommendations at the onset of the intervention, despite meeting inclusion criteria of engaging in structured exercise no more than 1 day per week. Reactivity to activity monitors has been documented for both adults and children (11, 20, 41); however, such reactivity tends to be short-lived. It is possible that the extrinsic reinforcement provided by the activity monitor caused a reactive response that was not representative of their habitual physical activity behavior at baseline. In the initial stages of the intervention, the research team worked with families on self- regulatory skills and goal-setting ideas that could be implemented within the family. Parents and children were encouraged to develop their own goals and work together to create family goals. Nearly all individual and family-based goals were oriented around the activity monitor to promote self-monitoring, a key factor in self-regulation (2). As the novelty or extrinsic reinforcement of the activity tracker lessened, motivation for physical activity behavior could have diminished as well, resulting in no significant change in physical activity over time.

In addition, in speaking with the parents we found that environmental barriers, such as daylight savings time, the holiday season, and the change in weather conditions played a large role in their families' physical activity participation. Parents are important social referents for child physical activity (52). During this intervention daylight savings time ended, meaning that participants lost an hour of daylight time and sunset occurred between 4:45 p.m. and 5:15 p.m. Discussions with parents and children suggested that this had a large effect on the amount of physical activity children were getting after school. Toward the end of the intervention, our participants' experienced roughly three weeks of daily rain and cold weather. With the majority of child physical activity occurring outside based on the self-regulation logs, these weather conditions could have had an impact on physical activity. Lastly, the Thanksgiving and Christmas holidays occurred at the end of the intervention and were mentioned by parents and children to be large factors in keeping their family's consistency in physical activity participation. These findings appear consistent with previous literature suggesting that levels of physical activity, particularly with children, vary with seasonality and weather conditions (9, 46). Although seasonal fluctuations in physical activity are commonly observed, research has suggested that the increase in activity in the warmer months typically do not compensate for the decrease in the colder months, resulting in an average decrease in physical activity of 7% yearly (5). Therefore, future research should place emphasis on overcoming environmental barriers to promote achieving adequate amounts of physical activity as children age. This may include looking for options to be physical active indoors to overcome changes in weather and daylight savings.

When examining the first set of models, the results suggested that parents were getting approximately 2825.18 ± 1282.77 fewer moves than their children on a daily basis. However, the rate at which their physical activity changed throughout the intervention was not unlike the rate of their child's change in physical activity. This validated inquiry into our second research aim of the relationship between child change in physical activity and parent change in physical activity. Given that maternal physical activity has been suggested to be a strong predictor of child physical activity (10, 23), our analysis only included the mothers' and children's data. Our results suggested that for every additional 1000 moves a mother made, their child made an additional 191.8 ± 57.3 moves per day. This finding is similar to that of Holm et al. (2012) where they found that for every additional 1000 steps that a mother took above her baseline step count, her child took an additional 196.0 steps (p = .001).

This significant relationship between maternal and child physical activity shows the role that parents' physical activity behavior can play in their child's daily physical activity levels. Research suggests that parents who are more active tend to provide more physical activity support (i.e. providing more opportunities, taking a more active role in facilitating physical activity behavior, modeling, direct and vicarious reinforcement) for their children (18, 28, 29) and are offering modeling opportunities to their children (10, 17). Although there are many possible mechanisms through which this phenomenon could be occurring, the most conclusive finding across this body of literature is simply that when parents are more active, their children tend to be more active (18, 23, 50). Based on this study, this relationship holds true for obese children, therefore interventions should target both maternal and child physical activity to fully engage children in physical activity.

The sample size limits the findings of this study. For this intervention we recruited for five weeks by a variety of methods and estimated to reach more than 8,000 people. We received interest from 12 families via email (two didn't meet inclusion criteria; two had time conflicts), which resulted in eight families that participated. One of the major factors affecting our recruitment may have been the possibility that parents were unable to identify if their child met the BMI inclusion criteria (> 85th percentile), as all participating children were at least 93rd percentile with the average being in the 97th percentile. This is not a recent phenomenon and has been well documented (12, 15, 26). Second, this family-based fitness study did not employ a control or active-control group. However, we were able to continuously monitor our participants daily physical activity consistently over the 10-weeks which is a strength in our design. Lastly, in attempting a more practical approach, we chose to only have the participants come in once per week. It could be that asking families to attend once per week was not enough to overcome barriers throughout the week related to physical activity, however, asking families to attend more than once a week is not feasible for many families.

In conclusion, this study shows that a mother's daily physical activity is significantly related to their obese child's daily physical activity. Meaning daily fluctuations in a mother's physical activity directly impacts daily patterns in obese children's physical activity. Therefore, interventions targeting obese children's physical activity should target altering the mother's physical activity as well as the child. Family interventions should also target overcoming barriers associated with outdoor physical activity.

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