# INCREASING PHYSICAL ACTIVITY IN ADOLESCENTS WITH MHEALTH: AN AGGREGATED N-OF-1 RCT

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Abstract: Social support and self-regulatory skills are two factors known to impact physical activity and sedentary behavior in adolescents. Given that adolescents are not meeting the recommended guidelines for physical activity (60 minutes daily or 9,000-14,000 steps) it is important to consider how these two factors can be incorporated in intervention programs. Current interventions development targeting social support and self-regulation are only just now beginning to capitalize on advancements in digital technology and most methods of intervention development are time-consuming and cost-inefficient. The aggregated N-of-1 RCT allows for an iterative process of intervention development that capitalizes on the use of technological interventions, and variability within participants to answer the question *for whom did the intervention work*, which is valuable in establishing the efficacy of behavioral intervention strategies prior to the inclusion in full-featured treatment packages. Ten adolescents (ages 13-18) participated in an N-of-1 RCT. Consistent with cybernetic control theory; adolescents set a daily physical activity goal. A Bioharness heart rate monitor assessed heart rate as proxy for goal attainment. Adolescents also self-monitored their physical activity in the Calorie Counter & Diet Tracker by MyFitnessPal app(commercially-available). Each night adolescents received a standardized text message providing feedback on goal attainment from a parent, nominated peer, or a behavioral health specialist (study staff); or no text message on control days. An Actigraph accelerometer recorded physical activity. The intervention demonstrated a significant effect for 30% of the sample. One adolescent (10%) increased their physical activity (step counts), while another two adolescents (20%) decreased time spent in sedentary activity. Feedback from all three providers demonstrated an increase over control in one of the two health behaviors. The effect of the intervention is consistent with other e-health and mobile health interventions targeting physical activity and sedentary behavior. The results suggest that some form of intervention can produce changes in these important behaviors by sending a text message from an influential person in an adolescent's life. This type of intervention module shows potential as it is easily administered and time-effective. The results have both research and clinical implications for intervention development.

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# CHAPTER I

## INTRODUCTION

Engagement in regular physical activity is associated with desirable health outcomes such as aerobic fitness, healthy blood pressure, decreased prevalence of obesity, and overall better psychological health (Sallis & Patrick, 1994; Janssen & LeBlanc, 2010). Given the benefits of regular physical activity, it is recommended that children between the ages of 6-17 years participate in at least 60 minutes of moderate to vigorous physical activity daily (Department of Health and Human Services, 2008), or between 9,000-14,000 steps with one study advocating 12,000 steps daily for adolescents (Silva, Fontana, Callahan, Mazzardo, & De Campos, 2014). However, research on physical activity patterns indicate that moderate-to-vigorous physical activity significantly declines between the ages of 9-15 years (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008). Thus, increasing adoption of this health promoting behavior proves to be a significant challenge (Schwarzer, 2008). Two factors that are known to modify health behaviors are social support and the use of self-regulatory skills (Patrick et al., 2001; Van der Horts, Paw, Twisk & Van Mechelen, 2007). These factors can be easily incorporated into interventions and can be facilitated by other individuals in an adolescent's life. However, it is unclear which system (i.e., family, peer, medical) is critical for modifying health behavior or if the ideal system varies across individual.

Mobile devices are well suited to supporting intervention development because they can intervene at the right time, in the right context and in a convenient way because they are always turned on (Gasser et al., 2006). Mobile technologies are particularly amenable to intervention strategies consistent with self-regulatory skills including goal-setting, self-monitoring, and goal review which have demonstrated efficacy in changing physical activity levels in adults (Michie, Abraham, Whittington, McAteer, Gupta, 2009) and adolescents (Attiasalo, Millunpalo, Kukkonen-Harjula, & Pasanen, 2006). The use of short message service (SMS) text messages has successfully been used to provide real-time feedback leading to significant reduction in weight-related variables (weight, waist circumference, BMI) in adults (Joo & Kim, 2007; Steinberg, Levine, Askew, Foley, & Bennett, 2013); as well as in children (Bauer, de Niet, Timman, & Kordy, 2010). SMS messaging is a viable avenue for intervention as adolescents ages 14-17 send a median of 100 texts per day (Lenhart, 2012).

Social support is another modifiable correlate of physical activity that can be targeted directly by interventions, has proven to impact physical activity in children and adolescents (Taylor, Baranowski, & Sallis, 1994) and can also be provided in the context of a SMS text message. There are a number of meaningful people in the adolescent's life that could provide this social support. The family is the primary context in which health behaviors are developed and maintained. Parental support, including verbal encouragement and instrumental support (e.g. transportation), shows a strong positive correlation with children and adolescent's level of physical activity (Van der Horts et al., 2007; Gustafson & Rhodes, 2006). While parents are an important agent for encouraging child and adolescent physical activity, as children move towards more autonomous behavior in adolescence they spend more time with peers who then exert more influence on health behaviors (Voorhees et al., 2005).

Interaction with peers can also have a significant effect on physical activity in adolescence, in the context of mentorship (Smith, 2011; Black et al., 2010), through the use of peer support (Beets, Vogel, Forlaw, Pitetti, & Cardinal, 2006) and encouragement (Duncan et al., 2005), and within common motivations of peer acceptance and increased friendship quality (Fitzgerald, Fitzgerald, & Aherene, 2012). Some literature suggests that peers exert more influence on physical activity behaviors in adolescence than do parents (Beets, et al., 2006).

Receiving targeted feedback on health behaviors by a healthcare professional has also shown significant changes in adolescent health behaviors (Patrick et al., 2001; Patrick et al., 2006). While research to date has examined parent, peer, and healthcare providers at the group level, static interventions do not account for the within-person variability, that allows for adaptive interventions, and therefore may be less effective (Adams, 2013). Some individuals may respond to only one treatment condition compared to another individual who may respond favorably to all treatments. However, this can only be captured when examining the effectiveness of an intervention at the individual level, as can be accomplished through small-n designs. Utilizing a medium that can incorporate social support from parents, peers, and healthcare professionals and allow for self-regulation strategies may provide the ideal intervention approach.

Self-regulatory skills have been identified as the most significant driver of health behavior change in adults (Michie et al., 2009), and self-monitoring is a significant predictor of intervention effectiveness for adolescents (Brannon & Cushing, 2015). Mobile technologies such as mobile health apps also have potential for incorporating self-regulation skills, yet the use of personalized and targeted feedback is not consistently incorporated (Brannon & Cushing, 2015). This disconnect may be that apps are not providing an opportunity for the prompting and practice of self-regulation skills, which could be facilitated by feedback from another individual. Therefore the question that has yet to be answered, is whether app developers should be encouraged to incorporate feedback into mobile health apps as well as whom should give that feedback. This study will take the first step in providing clarity on these important questions by utilizing a novel methodology that allows for experimental examination of which individual (parent, peer, healthcare professional) should be providing the feedback to increase physical activity in adolescents. One aim is to determine *for whom* the intervention is effective, and secondly to identify which individual should be providing the feedback. It is hypothesized that support from peers will have the largest effect on physical activity engagement, followed by parents and the healthcare professional, respectively. Lastly, it is expected that all three intervention conditions (i.e. peer, parent, and healthcare professional) will significantly increase physical activity compared to the use of a mobile health app alone, or control level.

# CHAPTER II

# METHODOLOGY

## Participants

Participants included ten adolescents, ages 13-18, from a community sample. Adolescents met the inclusion criteria as listed: 1) adolescent between the ages of 13-18, 2) who reported not meeting physical activity guidelines (i.e. 60 minutes each day), and 3) use an AT&T cell phone plan, own an Android smartphone, or were willing to use a smartphone provided to them.

## Research Method

The study methodology was an aggregated N-of-1 randomized controlled trial in which intervention days were the unit of randomization (Cushing, Walters, & Hoffman, 2013). In this design, feedback conditions were randomly assigned to study days within adolescents. Randomization was conducted utilizing a Latin square design to control for order effects across multiple conditions (Brooks, 2012). The number of intervention days was held constant across participants to ensure an equal "dose" of the intervention.

## Intervention

The intervention includes self-regulation strategies consistent with cybernetic control theory (Carver and Scheier, 1988), which includes goal-setting, self-monitoring, goal review and feedback. In an effort to standardize the goal-setting process, participants were provided instruction on the Center for Disease Control recommendations for adolescents between the ages of 13-18, which recommends 60 minutes of moderate to vigorous physical activity daily. Adolescents then provided a goal for the minutes of physical activity daily. Participants were instructed to perform any activity of choice as long as it met the definition of moderate to vigorous physical activity (e.g. requires a moderate amount of effort that increases heart rate and makes it difficult to carry a conversation). Self-monitoring occurred at the end of each day, when participants recorded their level of physical activity in a commercial app, Calorie Counter & Diet Tracker by MyFitnessPal. This app allows participants to record or track their physical activity from an auto populated list of common activities (e.g. jogging, swimming). Participants selected their activity from the list or entered their activity and the number of minutes performed. The app also allows participants to review their goal attainment at the end of each day by detailing their progress.

The intervention included four levels. Each participant randomly received feedback from a behavioral health specialist (study staff), parent (family), peer, or no feedback but access to the MyFitnessPal app, serving as an active control condition. Each feedback provider was given instructions to forward a standardized text to the participant based on their goal-attainment for the day, which was individually defined. If the participant met their physical activity goal for the day the feedback provider sent the following message: "Hey [Insert name]. Great job meeting your physical activity goal for the day. Keep up the great work." However, if participants did not meet their physical activity goal they received the following message: "It looks like you didn't meet your goal for the day. Try going for a short walk to get that heart rate up." It was expected that the feedback provided would modify physical activity for the following day. Therefore, everything was held static including the form of the feedback provided. The only aspect of the intervention that was manipulated was the individual providing the feedback.

**Procedure**

Participants were recruited through flyers placed around Stillwater, Edmond, and Oklahoma City, as well as a campus-wide email to faculty and staff at Oklahoma State University. Participants were invited to complete the study for 24-days and gave their assent for participation, as well as consent from the participant's parent. Participating peers and their parents were consented in person or via phone. Participants or peers who were 18 provided consent. All procedures were approved by the local Institutional review Board (IRB). Participants were compensated up to $40 for their participation in the study, based on their compliance to the protocol.

During an initial session, participants were equipped with a Zephyr Bioharness 3.0 as well as an Actigraph accelerometer. Participants were instructed to wear the Zephyr Bioharness for 12 hours each day. Participants also wore the Actigraph accelerometer, on their non-dominant hand, for 24-hours each day.

Following a brief review of the Center for Disease Control guidelines for physical activity (Corbin & Pangrazi, 1998), participants set a daily physical activity goal (in minutes). As part of a larger study, participants provided information on sleep, mood, social support, and physical activity via an app designed for ecological momentary assessment. Questions regarding sleep, physical activity, and engagement with feedback providers were answered once, and mood questions were answered four times each day. Each night participants received a standardized text message from one of three feedback providers on interventions days; and no text message on control days.

## Outcome Measures

**Physical Activity**. The Actigraph wAxis Sleep BT accelerometer (Actigraph LLC, Pensacola, FL) is a validated wireless activity monitor that allows for objective physical activity and sleep/wake measurements. The accelerometer records any motor movement of the individual and can sample movement at 1 second epochs. The actigraph was set to sample at 30Hz. The device was worn on the non-dominant hand of each adolescent for 24-hours a day, and is in accordance with the current National Health and Nutrition Examination Survey (NHANES) protocol (Toriano et al., 2008). Actigraph assessment of physical activity is highly correlated with direct observation assessment in children (McClain, Abraham, Brusseau, & Tudor-Locke, 2008). The wrist-worn actigraph has not been validated for physical activity in adolescents; therefore the algorithms used were based on validation in child samples (Freedson, Pober, & Janz, 2005). Step counts are accumulated on a per-epoch basis and are based on accelerometer data collected on the vertical axis. An algorithm present in the device firmware filters out the accelerometer's baseline noise level to help accurately accumulate the steps-per-epoch. The accelerometer also provided time spent in sedentary activity. Cut points were derived from a recent article providing counts per minute for wrist-placement accelerometry in children ages 7-13 (Kim, Lee, & Welk, 2014). Data were filtered so that a valid day was defined as having 10 or more hours (600 minutes) of monitor wear (excluding time sleeping), consistent with large epidemiological studies (Toriano et al., 2008).

## Process Measures

**Real-time physical activity assessment.** The Zephyr BioHarness 3.0 (Zephyr Technology, Auckland, New Zealand) is a wireless physiological monitoring device. The device includes a chest strap and an electronics module that attaches to the strap. The Bioharness was worn around the entire chest directly across the rib cage and sits just below the sternum. The device stores and transmits vital sign data including ECG, heart rate, respiration rate, body orientation and activity.

The Bioharness physiological monitoring device was utilized for real-time physical activity data capture to inform the type of feedback participants received. The Bioharness was synced to the ZephyrLife app on the participants' phone via bluetooth, and allowed participants to view their heart rate and breathing rate in real-time. Data was also transmitted via Bluetooth to a web portal operated by the Zephyr Corporation, via the ZephyrLife app to graphically record physiological data for each participant. The portal served as a medium through which the staff could assess the participant's goal attainment each day. Goal attainment was derived from the physiological heart rate data, to determine if participants were in the Max heart rate or aerobic heart rate ((220-age) * .60) for the specified goal each day. For example, if a participant set a physical activity goal for 30 minutes, their heart rate would need to be above the aerobic threshold to be counted as moderate to vigorous physical activity for 30 minutes throughout the day. In circumstances where heart rate data was not being transmitted to the web portal due to limited connectivity, goal attainment was determined from the participant's self-reported physical activity.

**Self-reported Physical Activity.** Participants provided self-reported physical activity levels in a commercial available mobile health app. Calorie Counter and Diet Tracker by MyFitnessPal has been identified to incorporate a number of evidence-based strategies for health behavior change including goal setting, self-monitoring, goal review, and social support (Brannon & Cushing, 2015). Participants were instructed to record their physical activity level in the app each day. Participants could choose from an auto populated list of common physical activities, or participants could create their own activity and enter the amount of time spent engaging in the physical activity. The app also allows for recording of dietary intake, however, that information was not included in the study. Once participants recorded their activity, it was posted to their virtual diary and was visible to the study staff. This information was used to determine the type of feedback participants received, only in situations when real-time physical activity data capture was unavailable, which was approximately 62% of the time.

**Manipulation Check:** In order to determine if the feedback providers were sending the text messages, a manipulation check was included in the final survey of the day. Participants were asked about their interactions with each feedback provider (e.g. "Did you discuss your physical activity goal with your parent today?"). Participants also indicated the method in which they discussed their physical activity with the feedback provider (i.e., text message, phone call, in person, email, none of the above). Out of the 105 manipulation check items, only 26 (25%) of the correct text messages were received.

Participants reported receiving a text message 48 times (46%) or had contact with a person not scheduled to interact with them regarding their physical activity. However, 16 times participants reported receiving a text message from the behavioral health specialist and text message transcripts contradicted 100% of those responses. This suggest that the responses provided may not be a valid.

## Data Analysis Plan

Descriptive statistics were analyzed for step counts and minutes of sedentary activity across the 10 participants and between treatment levels. Statistics were analyzed for a binary variable in which 0 indicated a control day and 1 indicated a treatment day, as well as at the intervention level (e.g., parent, peer, behavioral health specialist). All four treatment conditions were collapsed into one treatment category for the binary variable.  A second categorical variable indicated the intervention condition. Treatment days were lagged to account for the expected carryover effects (i.e., intervention on day N would affect physical activity on day N + 1). The *N* individual participants were distinguished by creating *N* -1 dummy-coded variables. To determine whether each participant needed their own error term, a homogenous variance model and heterogeneous variance model were calculated and compared. The difference between the -2 Log likelihood ratio was compared to the critical value on a normal chi-square distribution with degrees of freedom based on the difference in the number of parameters in the two models. If the difference was significant, a heterogeneous variance model was calculated to evaluate the effect of the intervention on each participant. The response to intervention within each of the ten participants was examined using a fixed-effects multilevel model to determine *for whom did the intervention work. N* - 1 dummy-coded variables were included as main effects and interactions with the subject level variable. Post-hoc contrasts were run to conduct pairwise comparisons of the intervention levels.

### Model Estimation and Missing Data

The current analyses were run using a Restricted Estimation Maximum Likelihood (REML) estimator. REML handles missing data as a full information method, meaning all available data is used to produce estimates and no cases are deleted (Peugh, 2010). Full information estimators produced accurate estimates at 35% missing data under conditions of data missing at random (MAR; Enders, 2001). Research suggests that deleting cases is worse than maximum likelihood imputation as it leads to biased estimates; and even when data is not missing at random, maximum likelihood is just as good as listwise deletion (Little, Jorgensen, Lang, & Moore, 2013). Therefore, due to the missing at random mechanism, the REML was used in the current analyses to address the 32% missing data in the sample.

CHAPTER III

FINDINGS

## Sample Characteristics

A total of 13 adolescents were enrolled in the study. Three participants (2, 3, 4) withdrew prior to completing study procedures. Reasons for withdrawal included difficulty finding peers to participate, concern for a busy schedule, and not wanting to wear the equipment. Participants included in the analyses were 10 adolescents between 13-18 years of age ($M$ = 16.7, $SD$ = 0.95). The sample included three males and seven females. Participants self-identified as Caucasian (90%), and Hispanic (10%). The sample was predominately middle class, 80% had a family income greater than $60,000 and 10% had a family income of $50,000-60,000 and $40,000-50,000.

## Treatment Outcomes

Descriptive statistics are presented in Table 1 by condition for each participant and aggregated over all 10 participants. Overall, step counts in the control condition were 10,092 ($SD$ = 569), whereas the step counts in the experimental conditions were 9,720 ($SD$ = 546), 9, 038 ($SD$ = 631), and 10,650 ($SD$ = 511) for the parent, peer, and behavioral health specialist conditions, respectively. The mean step counts are still well below the recommendation of 12,000 steps for adolescents (Silva et al., 2014). The first step was to evaluate whether or not treatment at any level produced an increase in physical activity relative to control. A homogeneous variance model and heterogeneous variance model were calculated to examine the variability in step counts across participants. The difference between the -2LL for the homogeneous variance model and (2575.08) and the heterogeneous variance model (2458.54) was significant ($p < .05$), therefore a heterogeneous variance model was used. There was no significant difference between step counts in the control condition and the treatment conditions, $F(9, 25) = 1.33$, $p > .05$. While there were no significant differences at the group level, the effect of the intervention should occur at the individual level. There were no significant differences across participants in their intervention effects (i.e., differences between control and treatment days), $F(27, 11) = 2.145$, $p > .05$.

**Common Findings: Step Counts**

There were no significant differences between control and treatment days for any participant when using the binary variable. To examine differences between each level of the intervention (i.e. parent, peer, behavioral health), a treatment level variable was included as the independent variable. Examination of error terms indicated a significant difference between the heterogeneous variance model (-2ll = 2091.504) and the homogeneous model (-2ll = 2201.994) at the $p < .05$ level ($\Delta$-2ll = 110.49, $\Delta df = 22$). Therefore the heterogeneous variance model was used allowing each participant to have their own error term. When examining the differences across levels for parent, peer, and behavioral health specialist compared to the control condition, there were no significant differences for Participants 1, 5, 6, 7, 8, 10, 11, 12, and 13. (Tables 2-4, Figure 1)

**Idiographic Findings: Step Counts**

Only one participant demonstrated a significant increase in step counts over the no feedback or control condition. Participant nine responded favorably in the behavioral health specialist condition, as this condition was higher than the no feedback condition. Participant nine increased their step count by 2, 490 steps when receiving feedback from a behavioral health specialist compared to receiving no feedback on goal attainment.

**Common Findings: Minutes Spent in Sedentary Activities**

Next, time spent in sedentary activities was examined as the dependent variable. The means for time spent in sedentary time were as follows: 455 ($SD$ = 23.74) in the parent condition, 490 ($SD$ = 28.25) in the peer condition, 468 ($SD$ = 24.92) in the behavioral health specialist condition, and 492 ($SD$ = 23.11) in the no feedback condition. On average, participants spent between 10 and 11 hours in sedentary activity which is slightly higher than a normative sample (9 hours; Ruiz, Ortega, Martinez-Gomez, 2010).

There was a significant difference between time spent in sedentary activity between the control days and treatment days, $F(9, 27) = 4.29$, $p < .05$. However, there were no significant differences across participants in their intervention effects, $F(27, 116) = .986$, $p > .05$. Examination at the binary level (i.e., all treatment vs. control), indicated that participant 7 had a significant difference between treatment and control days on minutes spent in sedentary activities. Specifically, participant 7 spent 348 more minutes in sedentary activities on control days when compared to treatment days. Similarly, participant 11 spent 186 more minutes in sedentary activity on control days compared to treatment days. Lastly, participant 10 also had a significant difference between treatment and control days, spending 95 more minutes in sedentary activities on treatment days compared to control days.

Both a heterogeneous variance model and homogeneous model was calculated. The data best fit a heterogeneous variance (-2ll = 1505.348) compared to the homogeneous variance model (-2ll = 1409.475), and was above the Chi square critical value at the .05 level ($\Delta$-2ll = 95.87, $\Delta df$ = 22). There were no significant differences in minutes spent in sedentary activities across conditions for participants 1, 5, 6, 8, 9, 10, 12 or 13.

**Idiographic Findings: Minutes Spent in Sedentary Activities**

Two participants displayed significant differences when comparing the treatment conditions to the no feedback condition. Participant 11 engaged in higher levels of sedentary activity in the no feedback condition as well as the behavioral health specialist condition relative to the control condition.  Specifically, participant 11 spent 237 more minutes in sedentary activities in the no feedback condition compared to the peer condition. In turn, participant 11 also spent 324 more minutes in the behavioral health specialist compared to the peer condition indicating a greater influence when receiving feedback from a peer.

Finally, one participant responded uniformly favorable to any treatment condition when compared to the no feedback condition. Participant seven engaged in 329 minutes in the no feedback condition compared to the parent condition, 284 more minutes compared to the peer condition, and 448 more minutes compared to the behavioral health specialist condition (see Tables 5-7, Figure 2).

# CHAPTER IV

## CONCLUSION

The purpose of the study was to test the impact of tailored feedback on physical activity goal attainment from three influential people in an adolescent's life. A notable strength of the current study was the reliance on an evidence-based health behavior change model that lends itself to mobile application (Carver & Sheier, 1989). Our study is the first to our knowledge that utilized a novel methodology (e.g., N-of-1 RCT) to examine what source of social support is likely to confer the greatest impact on physical activity.

The hypotheses were partially supported in that the treatment across the three conditions, (parents, peers, and behavioral health specialist) significantly increased physical activity as measured by step counts for one of our participants (10%) and decreased time spent in sedentary activity in an additional two participants (20%). Therefore, a total of 30% of the sample demonstrated significant differences in two important health behaviors compared to the control or no feedback condition; which is consistent with the results of other behavioral e-health and mobile health interventions (Stephans & Allen, 2003; Palermo, Wilson, Peters, Lewandowski, & Somhegyi, 2009). The results of the current study are also in line with evidence-based treatment packages for other important health factors, such as childhood anxiety, that suggests that 1 in 3 children treated will demonstrate clinically significant changes (Walkup et al., 2008). The results of the present study are particularly noteworthy given the consistency with well-established treatment programs that have undergone extensive research.

Changes across the two health behaviors is important as physical activity engagement and sedentary activity are two independent health behaviors that are associated with differing benefits and consequences (Bankoski et al., 2011) and require targeted intervention. A notable strength of the current intervention was the minimal time and effort needed to implement the intervention compared to other efficacious interventions that require weekly sessions (typically an hour) and involve a trained therapist. Therefore, not only did the intervention demonstrate success in changing these two health behaviors, it also appears to be extremely time- and potentially cost-efficient.

Consistent with the hypothesis, feedback from peers was influential for decreasing sedentary behavior in two of the participants, and was incrementally efficacious above feedback from a behavioral health specialist for one participant. Feedback from a behavioral health specialist induced behavior change for physical activity in one participant and sedentary behavior in another participant. It was also hypothesized that parental feedback would be higher than control which was consistent in one participant for decreasing sedentary behavior. Of note, three participants decreased time spent in sedentary activity when examining the treatment conditions in aggregate compared to control, suggesting that some form of intervention is effective for addressing sedentary behavior. Thus this study provides an initial step in examining the level that can confer the greatest impact, and how that level may differ amongst individuals, and is an area of research that warrants more attention as the field moves towards tailored intervention development.

The current intervention provides an example of an iteration of a potentially efficacious treatment for increasing physical activity and decreasing time spent in sedentary activity. The manipulation of the source of social support was an attempt to conduct an experimental study of a component that can be translated into an intervention package and then disseminated. Understanding *who the module works for and why* may be one avenue for providing tailored and individualized interventions. For example, it may be that some adolescents increase step counts by receiving text messages from a computer system designed to provide appropriate goal-setting and feedback on goal attainment while other adolescents are more influenced by personalized feedback from an influential person. Incorporation of effective intervention components could then be translated into a standard text message intervention or could be applied in a mobile health app and disseminated within a clinical setting.

In a final commercial product such as a mobile health app—clinicians can ask their patient to identify the person who can provide the social support to deliver the intervention. Patients that do not prefer the computerized solutions and want a more personal touch could then receive an intervention that incorporates parents and peers. Additionally, this intervention module could be added to a commercial app like the MyFitnessPal app that incorporates parent, peer, or behavioral health specialist feedback which is triggered when someone does or does not meet their physical activity goals.

In order to extend the current understanding of our intervention, additional research is warranted. Specifically, future studies should increase the sample size, which would provide statistical power to allow examination of the question *why the intervention works for some participants and not others* (Cushing, Walters, Hoffman, 2013), by incorporating additional mediators of intervention effectiveness. Understanding additional factors that influence intervention effectiveness and elucidate what makes intervention components favorable to each individual is the first step in providing tailored interventions to build upon the demonstrated improvements in physical activity when tailored feedback is provided (Bauer, de Niet, Timman, & Kordy, 2010; Suggs, 2006; Fjeldsoe, Marshall, & Miller, 2009).

The findings should be interpreted in light of several limitations. Because there was no baseline assessment of physical activity, we were unable to test whether there were significant changes in physical activity over baseline. Although a change in physical activity from baseline was not an aim of the study, future studies should incorporate the use of a baseline assessment to ascertain whether the intervention had a significant effect on physical activity. Additionally, a manipulation check was put in place to assess whether the participants were receiving the text messages from parents and peers as indicated in the protocol. Due to the logistics of data collection, the manipulation check was completed prior to the participant receiving the feedback. Future studies should incorporate a manipulation check that not only assesses whether text messages were sent, but also whether the content of the message was standardized. Additionally, there was 32% missing data that required imputation which may have contributed to null findings in some participants.

While every effort was made to hold things constant, we do not have a great deal of knowledge about all the changes that may have occurred as a result of participating in the study. It may be that participants had a global shift in their social ecological ecosystem in that individuals (e.g. parents, peers) provided general social support for physical activity even when they were not instructed to do so. It may also be that the app which was designed to be an attention control, may have created a change due to the inclusion of evidence-based strategies. Comparing the data from the current study with a control group receiving no intervention could provide additional clarity on these questions.

In conclusion, this study contributes to the growing knowledge base by examining the effectiveness of feedback on physical activity by three individuals in an adolescent's life. Mobile health technologies that incorporate the use of text messages stand to be a viable option for health promotion interventions (Fjeldsoe, Marshall, & Miller, 2009), specifically physical activity interventions (Bauer, deNiet, Timman, & Kordy, 2010; Stephens & Allen, 2013). Research more recently has transcended text messaging interventions to include mobile health apps, however, commercially available mobile health apps show limited congruence to evidence-based behavior change techniques (Brannon & Cushing, 2015). There is potential in creating a mobile health app that could provide this type of intervention, incorporating the individualized material and social support from parents, peers, or healthcare professionals.

REFERENCES


Adams, M.A., Sallis, J.F., Norman, G.J., Hovell, M.F., Hekler, E.B., Perata, E. (2013). An adaptive physical activity intervention for overweight adults: A randomized controlled trial. *Plos One*, *8*(12), e82901. doi: 10.1371/journal.pone.0082901

Aittasalo, M., Miilunpalo, S., Kukkonen-Harjula, K., Pasanen, M. (2006). A randomized intervention of physical activity promotion and patient self-monitoring in primary health care. *Preventive Medicine*, *42*(1), 40-46. doi:10.1016/j.ypmed.2005.10.003

Bankoski, A., Harris, T. B., McClain, J. J., Brychta, R. J., Caserotti, P., Chen, K. Y., ... & Koster, A. (2011). Sedentary activity associated with metabolic syndrome independent of physical activity. *Diabetes Care*, *34*(2), 497-503. doi: 10.1016/j.yspm.2011.08.072

Bauer, S., de Niet, J., Timman, R., & Kordy, H. (2010). Enhancement of care through self-monitoring and tailored feedback via text messaging and their use in the treatment of childhood overweight. *Patient Education and Counseling*, *79*(3), 315-319. doi: 10.1016/j.pec.2010.03.014

Beets, M. W., Vogel, R., Forlaw, L., Pitetti, K. H., & Cardinal, B. J. (2006). Social support and youth physical activity: the role of provider and type. *American Journal of Health Behavior*, *30*(3), 278-289. doi: 10.5993/ajhb.30.3.6

Black, M. M., Hager, E. R., Le, K., Anliker, J., Arteaga, S. S., DiClemente, C., ... & Wang, Y. (2010). Challenge! Health promotion/obesity prevention mentorship model among urban, black adolescents. *Pediatrics*, *126*(2), 280-288. doi: 10.1542/peds.2009-1832

Brannon, E.E., Cushing, C.C. (2015). Is there an app for that? Translational science of pediatric behavior change. *Journal of Pediatric Psychology,* 40(4), 373-384. doi:1.1093/jpepsy/jsu108

Brofenbrenner, U. (1994). Ecological models of human development. In *International Encyclopedia of Education*, *Vol 3.* 2nd ed. Oxford: Elsevier.

Brooks, J. L. (2012). Counterbalancing for serial order carryover effects in experimental condition orders. *Psychological Methods*, *17*(4), 600-614. doi: 10.1037/a0029310

Carver, C. S., & Scheier, M. F. (1982). Control theory: A useful conceptual framework for personality–social, clinical, and health psychology. *Psychological Bulletin*, *92*(1), 111-135. doi: 10.1037//0033-2909.92.2.111

Corbin, C., and Pangrazi, R.P. (1998). *Physical activity for children: A statement of guidelines*, Reston, VA: NASPE Publications 1-21.

Cushing, C. C., Walters, R. W., & Hoffman, L. (2013). Aggregated N-of-1 randomized controlled trials: Modern data analytics applied to a clinically valid method of intervention effectiveness. *Journal of Pediatric Psychology*, *39*(2), 138-150. doi: 10.1093/jpepsy/jst083

Department of Health and Human Services (2008). The 2008 Physical Activity Guidelines for Americans. Retrieved from www.health.gov/paguidleines/guidelines.

Duncan, S. C., Duncan, T. E., & Strycker, L. A. (2005). Sources and types of social support in youth physical activity. *Health Psychology, 24*(1), 3-10. doi:10.1037/0278-6133.24.13

Enders, C.K. (2001). The performance of the full information maximum likelihood estimator in multiple regression models with missing data. *Educational and Psychological Measurement*, *61*(5), 713-740. doi:10.1177/00131640121971482

Fitzgerald, A., Fitzgerald, N., & Aherne, C. (2012). Do peers matter? A review of peer and/or friends' influence on physical activity among American adolescents. *Journal of Adolescence*, *35*(4), 941-958. doi: 10.1016/j.adolescence.2012.01.002

Fjeldsoe, B. S., Marshall, A. L., & Miller, Y. D. (2009). Behavior change interventions delivered by mobile telephone short-message service. *American Journal of Preventive Medicine*, *36*(2), 165-173. doi: 10.1016/j.aepre.2008.09.040

Freedson, P.S., Pober, D., Janz, K.F. (2005). Calibration of accelerometer output for children, *Medical Science in Sports and Exercise, 37*(11), S523-530. doi: 10.129/01.mss.0000185658.28284.ba

Gasser, R., Brodbeck, D., Degen, M., Luthiger, J., Wyss, R., & Reichlin, S. (2006). Persuasiveness of a mobile lifestyle coaching application using social facilitation. In *Persuasive Technology* (pp. 27-38). Springer Berlin Heidelberg.

Gustafson, S.L., Rhodes, R.E. (2006). Parental correlates of physical activity in children and early adolescents, *Sports Medicine*, *36*(1), 79-97. doi: 10.2165/00007256-200636010-00006

Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity*, *7*(40), 1-16. doi: 10.1186/1479-5868-7-40.

Joo, N. S., & Kim, B. T. (2007). Mobile phone short message service messaging for behaviour modification in a community-based weight control programme in Korea. *Journal of Telemedicine and Telecare*, *13*(8), 416-420. doi: 10.1258/135763307783064331

Kim, Y., Lee, J. M., Peters, B. P., Gaesser, G. A., & Welk, G. J. (2014). Examination of different accelerometer cut-points for assessing sedentary behaviors in children. *PloS One*, *9*(4), e90630. doi: 10.1371/journal.pone.0090630

Lenhart, A. (2012, March 19). Teens, smartphones & texting. Retrieved from http://www.pewinternet.org/2012/03/19/teens-smartphones-texting/

Little, T.D., Jorgensen, T.D., Lang, K.M., & Moore, E.W.G. (2013). On the joys of missing data. *Journal of Pediatric Psychology*, *39*(2), 151-162. doi: 10.1093/jpepsy/jst048

McClain, J. J., Abraham, T. L., Brusseau Jr, T. A., & Tudor-Locke, C. (2008). Epoch length and accelerometer outputs in children: comparison to direct observation. *Medicine and Science in Sports and Exercise*, *40*(12), 2080-2087. doi: 10.1249/MSS.0b013e3181824d98

Michie, S., Abraham, C., Whittington, C., McAteer, J., Gupta, S. (2009). Effective techniques in healthy eating and physical activity interventions: A meta-regression. *Health Psychology, 28*(6), 690-701. doi: 10. 1037/a0016136

Nader, P.R., Bradley, R.H., Houts, R.M., McRitchie, S.L., O'Brien, M. (2008). Moderate-to-vigorous physical activity from ages 9 to 15 years. *Journal of American Medical Association, 300*(3), 295-305. doi: 10.1001/jama.300.3.295

Ornelas, I. J., Perreira, K. M., & Ayala, G. X. (2007). Parental influences on adolescent physical activity: a longitudinal study. *International Journal of Behavioral Nutrition and Physical Activity*, *4*(1), 3.

Palermo, T. M., Wilson, A. C., Peters, M., Lewandowski, A., & Somhegyi, H. (2009). Randomized controlled trial of an Internet-delivered family cognitive–behavioral therapy intervention for children and adolescents with chronic pain. *Pain*, *146*(1), 205-213. doi: 10.1016/j.pain.200.07.034

Patrick, K., Sallis, J. F., Prochaska, J. J., Lydston, D. D., Calfas, K. J., Zabinski, M. F., ... & Brown, D. R. (2001). A multicomponent program for nutrition and physical activity change in primary care: PACE+ for adolescents. *Archives of Pediatrics & Adolescent Medicine*, *155*(8), 940-946. doi: 10.1001/archpedi.155.8.940

Patrick, K., Calfas, K.J., Norman, G.J., Zabinski, M.F., Sallis, J.F., Rupp, J.,… & Covin, J., Cella, J. (2006). Randomized controlled trial of a primary care and home-based intervention for physical activity and nutrition behaviors: PACE+ for adolescents, *Archives in Pediatric Adolescents Medicine, 160*(2), 128-136. doi: 10.1001/archpedi.160.2.128

Peugh, J.L., (2010). A practical guide to multilevel modeling. *Journal of School Psychology, 48*(1), 85-112. doi: 10.1016/j.jsp.2009.09.002

Riley, W. T., Cesar, A., & Rivera, D. E. (2014, August). The importance of behavior theory in control system modeling of physical activity sensor data. In *Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE* (pp. 6880-6883). IEEE.

Ruiz, J. R., Ortega, F. B., Martínez-Gómez, D., Labayen, I., Moreno, L. A., De Bourdeaudhuij, I., ... & Sjöström, M. (2011). Objectively measured physical activity and sedentary time in European adolescents the HELENA study. *American Journal of Epidemiology, 174*(2), 173-184. doi: 10.1093/aje/kwr068

Sallis, J. F., & Patrick, K. (1994). Physical activity guidelines for adolescents: consensus statement. *Pediatric Exercise Science*, *6*, 302-302.

Schwarzer, R. (2008). Modeling health behavior change: How to predict and modify the adoption and maintenance of health behaviors. *Applied Psychology*, *57*(1), 1-29. doi: 10.1111/j.1464-0597.2007.00325

Silva, M. P., Fontana, F. E., Callahan, E., Mazzardo, O., & De Campos, W. (2014). Step-Count Guidelines for Children and Adolescents: A Systematic Review. *Journal of Physical Activity & Health*. doi: 10.1123/jpah.2014-0202

Smith, L. H. (2011). Piloting the use of teen mentors to promote a healthy diet and physical activity among children in Appalachia. *Journal for Specialists in Pediatric Nursing*, *16*(1), 16-26. doi: 10.111/j.1744-6155.2010.00264

Steinberg, D. M., Levine, E. L., Askew, S., Foley, P., & Bennett, G. G. (2013). Daily text messaging for weight control among racial and ethnic minority women: Randomized controlled pilot study. *Journal of Medical Internet Research*, *15*(11). doi: 10.2196/jmir.2844

Stephens, J., & Allen, J. (2013). Mobile phone interventions to increase physical activity and reduce weight: a systematic review. *Journal of Cardiovascular Nursing*, *28*(4), 320-329. doi: 10.1097/JCN.0b013e318250a3e7

Suggs, L. S. (2006). A 10-year retrospective of research in new technologies for health communication. *Journal of Health Communication*, *11*(1), 61-74. doi: 10.1080/10810730500461083

Taylor, W. C., Baranowski, T., & Sallis, J. F. (1994). Family determinants of childhood physical activity: a social-cognitive model. *Advances in Exercise Adherence*, 319-342.

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. *Medicine and Science in Sports and Exercise*, *40*(91), 181.

Van der Horst, K., Paw, M. J. C. A., Twisk, J. W., & Van Mechelen, W. (2007). A brief review on correlates of physical activity and sedentariness in youth. *Medicine and*

*Science in Sports and Exercise, 39*(8), 1241. doi: 10.1249/mss.0b013e3180596bf35

Voorhees, C. C., Murray, D., Welk, G., Birnbaum, A., Ribisl, K. M., Johnson, C. C.... & Jobe, J. B. (2005). The role of peer social network factors and physical activity in adolescent girls. *American Journal of Health Behavior, 29*(2), 183-190. doi: 10.5993/ajhb.29.2.9

Walkup, J.T. Albano, A.M., Piacentini, J., Birmaher, B., Compton, S.N., Sherrill J.T…. & Kendall, P.C. (2008). Cognitive behavioral therapy, Sertraline, or a combination in childhood anxiety, *New England Journal of Medicine*, *359*, 2753-2766. doi: 10.1056/NEJMoa0804633

Wilson, D. K., & Lawman, H. G. (2009). Health promotion in children and adolescents: An integration of the biopsychosocial model and ecological approaches to behavior change. *Handbook of Pediatric Psychology*, 603-617.

APPENDICES

Table 1. *Descriptive Statistics Between and Within Participants*

| **Participant** | **Step Counts (Mean, *SD*)** | | | | **Sedentary Activity (Mean, *SD*)** | | | | **Missing Data (%)*** |
|---|---|---|---|---|---|---|---|---|---|
| | Control | Parent | Peer | Behavioral Health | Control | Parent | Peer | Behavioral Health | |
| 1 | 15,609 (1391.21) | 12, 597 (1880.70) | 15,367 (1361.18) | 16,219 (625.01) | 393 (106.83) | 372 (61.61) | 367 (67.84) | 405 (59.23) | 29.2 |
| 5 | 9,249 (1772.74) | 8,368 (1152.64) | 5,832 (1428.88) | 8,633 (816.15) | 566 (67.47) | 591 (20.95) | 514 (102.50) | 550 (42.78) | 12.5 |
| 6 | 8,860 (749.58) | 7,849 (1801.10) | 8,515 (833.55) | 9,824 (877.99) | 490 (58.44) | 499 (82.69) | 511 (63.57) | 497 (43.81) | 0 |
| 7 | 11,536 (2289) | 9,535 (784.78) | 9,159 (751.23) | 10,718 (815.11) | 575 (56.50) | 256 (35.42) | 325 (107.01) | 211 (67.10) | 41.7 |
| 9 | 6,860 (388.10) | 8,415 (753.53) | 7,061 (1133.53) | 9,278 (716.32) | 604 (34.12) | 587 (25.08) | 680 (21.25) | 633 (34.30) | 0 |
| 10 | 9,431 (795.26) | 8,643 (794.87) | 8,574 (1288.46) | 8,830 (1137.95) | 424 (40.04) | 477 (52.82) | 503 (40.53) | 503 (51.53) | 0 |
| 11 | 12,306 (1998.5) | 12, 086 (970.50) | --------- | 10,415 (564) | 549 (98.50) | 346 (5.0) | 312 | 497 (164.0) | 70.8 |
| 12 | --------- | 6,829 (634.50) | ---------- | 9,380 (1256) | --------- | 419 (17.50) | ----------- | 517 (9.0) | 70.8 |
| 13 | 12,096 (1570.39) | 12,578 (619.14) | 12,804 (878.59) | 13,869 (2446.14) | 402 (63.25) | 419 (41.45) | 388 (23.19) | 316 (50.12) | 20.8 |
| Overall | 10,092 (569.11) | 9,720 (545.73) | 9,038 (630.74) | 10,650 (511.13) | 492 (23.11) | 455 (23.74) | 490 (28.25) | 468 (24.92) | 32 |

** Participant 8 had 79.2% missing and therefore does not have enough data for descriptive information.*

Table 2. *Final Results using Fixed-Effects Model with Constant (Heterogenous) Variance for Step Counts: Parent Condition in Relation to Control*

| | Differences relative to participant 12 | | | | Unique effects for each participant | | | |
|---|---|---|---|---|---|---|---|---|
| **Fixed effects** | **Estimate** | ***SE*** | ***t*** | ***p*** | **Estimate** | ***SE*** | ***t*** | ***p*** |
| Intercept | 4910 | 3228.15 | - | - | - | - | - | - |
| Participant 1 | -4320.42 | 3855.75 | -1.12 | 0.29 | -2732.5 | 1653.64 | -1.65 | 0.11 |
| Participant 5 | -1818.35 | 3779.27 | -0.48 | 0.64 | -230.43 | 1466.5 | -0.16 | 0.88 |
| Participant 6 | -297.23 | 3700.45 | -0.08 | 0.94 | 1290.7 | 1249.44 | 1.03 | 0.33 |
| Participant 7 | -4815.86 | .834.21 | -1.26 | 0.24 | -3227.94 | 1602.79 | -2.01 | 0.08 |
| Participant 8 | 7062.08 | 5542 | 1.27 | 0.22 | 8650 | 4310.63 | 2.01 | 0.09 |
| Participant 9 | 216.33 | 3712.49 | 0.06 | 0.96 | 1804.25 | 1284.65 | 1.4 | 0.17 |
| Participant 10 | 313.23 | 3622.95 | 0.09 | 0.93 | 1901.15 | 996.75 | 1.91 | 0.14 |
| Participant 11 | -1631.27 | 4161.81 | -0.39 | 0.7 | -43.35 | 2277.8 | -0.02 | 0.99 |
| Participant 12 | 1587.92 | 3483.14 | 0.46 | 0.67 | 1587.92 | 3483.14 | 0.46 | 0.67 |
| Participant 13 | -2024.96 | 3759.5 | -0.54 | 0.61 | -437.04 | 1414.77 | -0.31 | 0.76 |
| Model Fit | | | | | | | | |
| -2LL | | 2091.5 | | | | | | |

Table 3. *Final Results using Fixed-Effects Model with Constant (Heterogenous) Variance for Step Counts: Peer Condition in Relation to Control*

| | **Differences relative to participant 12** | | | | **Unique effects for each participant** | | | |
|---|---|---|---|---|---|---|---|---|
| **Fixed effects** | **Estimate** | ***SE*** | ***t*** | ***p*** | **Estimate** | ***SE*** | ***t*** | ***p*** |
| Intercept | 4910 | 3228.15 | - | - | - | - | - | - |
| Participant 1 | -2230 | 4192.53 | -0.53 | 0.61 | 1489.1 | 1410.58 | 1.06 | 0.31 |
| Participant 5 | -6209.69 | 4099.32 | -1.52 | 0.17 | -2489.69 | 1103.12 | -2.26 | 0.06 |
| Participant 6 | -4066.05 | 4118.34 | -0.99 | 0.35 | -346.05 | 1171.81 | -0.3 | 0.77 |
| Participant 7 | -7095.16 | 4247.16 | -1.67 | 0.13 | -3375.16 | 1565.48 | -2.16 | 0.07 |
| Participant 8 | -11276 | 4854.15 | -2.32 | <.05 | -7556 | 2824.03 | -2.68 | 0.07 |
| Participant 9 | -3222.14 | 4084.53 | -0.79 | 0.45 | 497.86 | 1046.82 | 0.48 | 0.65 |
| Participant 10 | -986.9 | 4080.36 | -2.54 | 0.82 | 2733.1 | 1030.4 | 2.65 | 0.12 |
| Participant 11 | -5803.42 | 5700.82 | -1.02 | 0.33 | -2083.42 | 4112.39 | -0.51 | 0.63 |
| Participant 12 | 3720 | 3948.11 | 0.94 | 0.38 | 3720 | 3948.11 | 0.94 | 0.98 |
| Participant 13 | -3262.79 | 4081.29 | -0.8 | 0.45 | 457.21 | 1034.09 | 0.44 | 0.7 |
| Model Fit | | | | | | | | |
| -2LL | | 2091.5 | | | | | | |

Table 4. *Final Results using Fixed-Effects Model with Constant (Heterogenous) Variance for Step Counts: Behavioral Health Specialist Condition in Relation to Control*

| | **Differences relative to participant 12** | | | | **Unique effects for each participant** | | | |
|---|---|---|---|---|---|---|---|---|
| **Fixed effects** | **Estimate** | ***SE*** | ***t*** | ***p*** | **Estimate** | ***SE*** | ***t*** | ***p*** |
| Intercept | 4910 | 3228.15 | - | - | - | - | - | - |
| Participant 1 | -2134.6 | 3820.47 | -0.56 | 0.59 | 2339.8 | 1388.6 | 1.69 | 0.13 |
| Participant 5 | -4612.95 | 3777.38 | -1.22 | 0.26 | -138.54 | 1265.25 | -0.11 | 0.91 |
| Participant 6 | -3742.97 | 3698.22 | -1.01 | 0.34 | 731.43 | 1004.54 | 0.73 | 0.53 |
| Participant 7 | -6293.54 | 3858.79 | -1.63 | 0.14 | -1819.14 | 1490.81 | -1.22 | 0.27 |
| Participant 8 | -885.4 | 5355.25 | -0.17 | 0.87 | 3589 | 4001.37 | 0.9 | 0.4 |
| Participant 9 | -1983.53 | 3746.97 | -0.53 | 0.61 | 2490.87 | 1171.33 | 2.13 | <.05 |
| Participant 10 | -2925.8 | 3688.71 | -0.79 | 0.45 | 1548.6 | 968.94 | 1.6 | 0.23 |
| Participant 11 | -6540.8 | 4209.84 | -1.55 | 0.15 | -206.4 | 2248.33 | -0.92 | 0.37 |
| Participant 12 | 4474.4 | 3559.18 | 1.26 | 0.25 | 4474.4 | 3559.18 | 1.26 | 0.25 |
| Participant 13 | -2108.22 | 3770.08 | -0.56 | 0.59 | 2366.18 | 1243.29 | 1.9 | 0.13 |
| Model Fit | | | | | | | | |
| -2LL | | 2901.5 | | | | | | |

Table 5. *Final Results Using Fixed-Effects Model with Constant (Heterogeneous) Variance for Time Spent in Sedentary Activities: Parent Condition in Relation to Control*

| | **Differences relative to Participant 12** | | | | **Unique effects for each participant** | | | |
|---|---|---|---|---|---|---|---|---|
| Fixed effects | Estimate | *SE* | *t* | *p* | Estimate | *SE* | *t* | *p* |
| Intercept | 467.06 | 189.27 | - | - | - | - | - | - |
| Participant 1 | 102.31 | 196.34 | 0.52 | 0.62 | 36.24 | 52.23 | 0.69 | 0.5 |
| Participant 5 | 167.1 | 205.79 | 0.82 | 0.44 | 101.93 | 80.8 | 1.27 | 0.22 |
| Participant 6 | 88.28 | 194.19 | 0.46 | 0.67 | 22.21 | 43.45 | 0.51 | 0.62 |
| Participant 7 | -262.73 | 207.56 | -1.27 | 0.24 | -328.89 | 85.2 | -3.86 | <.05 |
| Participant 8 | -101.94 | 289.75 | -0.35 | 0.73 | -168 | 219.39 | -0.77 | 0.46 |
| Participant 9 | 34.59 | 196.27 | 0.18 | 0.87 | -31.47 | 51.95 | -0.61 | 0.57 |
| Participant 10 | 124.97 | 192.13 | 0.65 | 0.54 | 58.91 | 33.06 | 1.78 | 0.12 |
| Participant 11 | -118.13 | 219.53 | -0.54 | 0.6 | -184.19 | 111.23 | -1.66 | 0.11 |
| Participant 12 | -66.06 | 189.27 | -0.35 | 0.05 | -66.06 | 189.27 | -0.35 | 0.74 |
| Participant 13 | 65.55 | 194.99 | 0.34 | 0.75 | -0.51 | 46.89 | -0.01 | 0.99 |
| Model fit | | | | | | | | |
| -2LL | | | 1409.475 | | | | | |

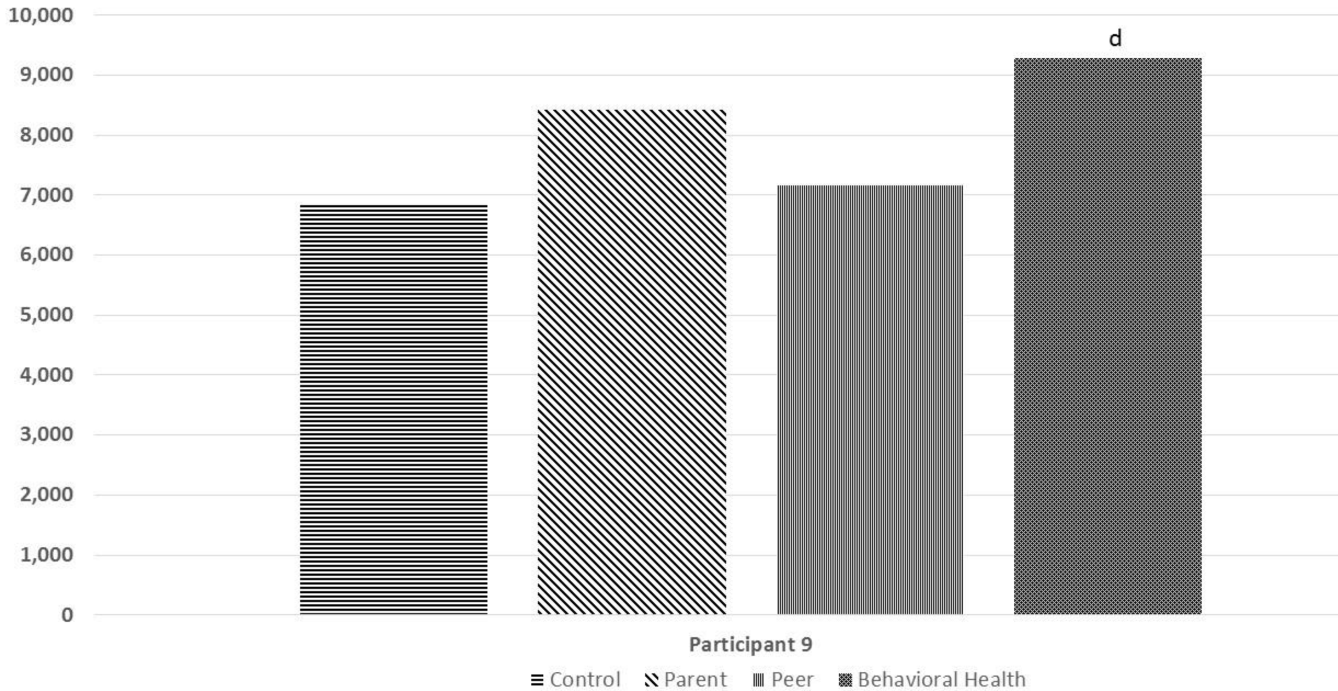
Table 6. *Final Results Using Fixed-Effects Model with Constant (Heterogeneous) Variance for Time Spent in Sedentary Activities: Peer Condition in Relation to Control*

| | **Differences relative to Participant 12** | | | | **Unique effects for each participant** | | | |
|---|---|---|---|---|---|---|---|---|
| Fixed effects | Estimate | *SE* | *t* | *p* | Estimate | *SE* | *t* | *p* |
| Intercept | 467.06 | 189.27 | - | - | - | - | - | - |
| Participant 1 | -66.94 | 207.53 | -0.32 | 0.76 | -123.99 | 0.03 | -4157 | 1 |
| Participant 5 | 171.92 | 216.06 | 0.8 | 0.45 | 114.86 | 60.11 | 1.91 | 0.08 |
| Participant 6 | 22.06 | 207.53 | 0.11 | 0.92 | -35 | 0.03 | -1173.63 | 1 |
| Participant 7 | -226.98 | 230.66 | -0.98 | <.05 | -284.04 | 100.67 | -2.82 | <.05 |
| Participant 8 | 294.06 | 328.68 | 0.9 | 0.38 | 237 | 254.87 | 0.93 | 0.37 |
| Participant 9 | 179.24 | 216.57 | 0.83 | 0.43 | 122.18 | 61.92 | 1.97 | 0.08 |
| Participant 10 | 146.23 | 214.42 | 0.68 | 0.51 | 89.17 | 53.91 | 1.66 | 0.11 |
| Participant 11 | -179.62 | 231.36 | -0.78 | 0.45 | -236.69 | 102.27 | -2.31 | .<.05 |
| Participant 12 | -57.06 | 207.53 | -0.28 | 0.79 | -57.06 | 207.53 | -0.28 | 0.79 |
| Participant 13 | 52.44 | 212.88 | 0.25 | 0.81 | -4.62 | 47.41 | -0.1 | 0.92 |
| Model fit | | | | | | | | |
| -2LL | | | 1409.475 | | | | | |

Table 7. *Final Results Using Fixed-Effects Model with Constant (Heterogeneous) Variance for Time Spent in Sedentary Activities: Behavioral Health Specialist Condition in Relation to Control*

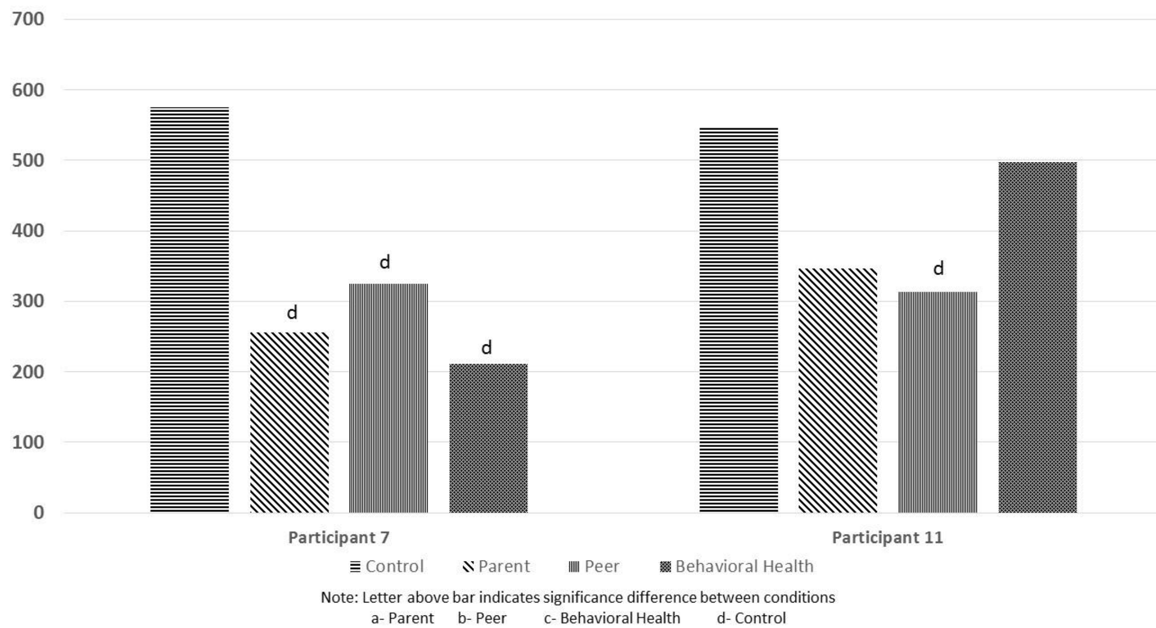
| | **Differences relative to Participant 12** | | | | **Unique effects for each participant** | | | |
|---|---|---|---|---|---|---|---|---|
| Fixed effects | Estimate | *SE* | *t* | *p* | Estimate | *SE* | *t* | *p* |
| Intercept | 467.06 | 189.27 | - | - | - | - | - | - |
| Participant 1 | 17.19 | 207.77 | 0.08 | 0.94 | 73.66 | 39.75 | 1.85 | 0.1 |
| Participant 5 | -21.26 | 209.99 | -0.1 | 0.92 | 35.21 | 50.07 | 0.7 | 0.51 |
| Participant 6 | 11.96 | 207 | 0.06 | 0.96 | 68.42 | 35.5 | 1.93 | 0.1 |
| Participant 7 | -504.79 | 212 | -2.38 | <.05 | -448.32 | 57.93 | -7.74 | <.05 |
| Participant 8 | -160.47 | 303.03 | -0.53 | 0.6 | -104 | 224.13 | -0.46 | 0.65 |
| Participant 9 | -35.94 | 210.45 | -0.17 | 0.87 | 20.53 | 51.95 | 0.4 | 0.71 |
| Participant 10 | 46.44 | 206.6 | 0.23 | 0.83 | 102.91 | 33.06 | 3.11 | <.05 |
| Participant 11 | 30.83 | 227.4 | 0.14 | 0.9 | 87.3 | 100.6 | 0.87 | 0.4 |
| Participant 12 | 56.47 | 203.94 | 0.28 | 0.79 | 56.47 | 203.94 | 0.28 | 0.79 |
| Participant 13 | -43.47 | 203.94 | -0.21 | 0.84 | 13 | 0.03 | 435.92 | 1 |
| Model fit | | | | | | | | |
| -2LL | | | 1409.475 | | | | | |

Figure 1. Idiographic Findings for Step Counts




Note: Letter above the bar indicates significant difference between conditions
a- Parent b- Peer c- Behavioral Health d- Control

Figure 2. Idiographic Findings for Time Spent in Sedentary Activities



## LITERATURE REVIEW

Engagement in regular physical activity is associated with desirable health outcomes such as aerobic fitness, healthy blood pressure, decreased risk of obesity, and overall better psychological health (Sallis & Patrick, 1994; Janssen & LeBlanc, 2010). Given the benefits of regular physical activity, it is recommended that children between the ages of 6-17 years participate in at least 60 minutes of moderate to vigorous physical activity daily (Department of Health and Human Services, 2008). However, research on physical activity patterns indicate that while children may meet recommendations for moderate-to-vigorous physical activity, there is a significant reduction in physical activity in adolescents between the ages of 9-15 years (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008). Behaviors in adolescence are also likely to persist into adulthood, suggesting a limited window of opportunity to change or develop long-term healthy lifestyle behaviors (Taylor, Blair, Cumings, Wun, & Malina, 1999). While evidence supports the positive benefits of engagement in regular physical activity, health-related behavior change remains a difficult process.

Individuals are key contributors to the development and maintenance of their own health promoting habits. One notable theory of behavioral self-regulation, Cybernetic Control Theory (Carver and Scheier, 1982), provides a framework for identifying the mechanisms of goal-pursuit or self-regulation. Individuals examine their current condition (input function) and compare that condition against an ideal reference point (comparator). If a discrepancy exists among the current condition and the reference point, individuals will engage in a behavior to reduce this discrepancy. The behavior (output function) impacts the person's environment which should then alter the current condition to align with the reference point. The individual will then review their progress towards reaching the reference point, and if a discrepancy still exists among the current condition and reference point a new behavior is warranted.

**Cybernetic Control Theory**

The specific self-regulation strategies consistent with Cybernetic Control Theory (goal-setting, self-monitoring, reviewing progress, and feedback) have been incorporated in a number of studies to promote physical activity in children, adolescents, and adults. These theory-based strategies have shown efficacious for physical activity when utilized as a component of interventions (Sallis, 1997); while specific components (e.g. self-monitoring, feedback) of the theory alone have also been demonstrated as efficacious in improving physical activity in children and adolescents (Aittasalo et al., 2006). Studies that have incorporated the use of self-management skills such as goal-setting, self-monitoring, review of goals, and problem-solving, housed within a school curriculum program report statistically significant increases in the physical activity level of school-age children (Sallis et al., 1997). Although not termed control theory, recent reviews lend support to the use of the cluster of self-regulatory behaviors noted above for increased effectiveness in terms of weight loss, change in dietary outcomes, change in physical activity, and combined outcomes in adults (Greaves et al., 2011).

Interventions have also focused on increasing the amount of feedback participants receive to assist in goal-attainment. One study that aimed to improve healthy eating and increase physical activity, instructed adolescents to create a specific goal and then to self-monitor their behavior to determine whether they met their goal (Patrick et al., 2006). Adolescents also received feedback from healthcare providers on their goal attainment and were provided instructions on how to reach the specified goal. Adolescents in the intervention group significantly reduced their sedentary behaviors, and intervention boys significantly increased their physical activity. While increased feedback has been suggested to be effective in this study, few studies in the literature have manipulated the amount or source of feedback provided to participants.

Indeed, developmental research suggests that the ability to effectively set realistic and attainable goals requires training in goal-setting (Schunk, 2006). In this way, children and adolescents may need additional assistance to set realistic goals in order to self-regulate behavior. For instance, children may rely heavily on the advice of their parents and teachers at school, whereas adolescents might be primarily affected by peer relationships. Support or feedback from other influential people who directly interact with the child or adolescent, can be conceptualized as a trigger for self-regulation behaviors. Direct feedback on goal attainment may lead to a reflection on the discrepancy between goal behavior and current behavior. Therefore, examination of the influence of interactions among the child/adolescent and their parents, peers, school system, healthcare system, or community for the promotion of self-regulation strategies is warranted.

Despite the review indicated that self-regulation strategies are effective for adolescents, when examined in aggregate the results are less positive. Indeed, research supports the fact that self-monitoring is the only self-regulation strategy that is a meaningful predictor of physical activity effect size (Brannon & Cushing, *under review*). However, the other components of control theory (e.g. goal-setting, feedback, review) are not significant predictors in the effectiveness of health promotion interventions to promote physical activity in children and adolescents (Brannon & Cushing, *under review*). The authors hypothesized that these strategies were not effectively taught and fostered in children and adolescents, the skills were not as salient for children and adolescents seeking health promotion, or that additional support from other systems is needed for children and adolescents to effectively utilize self-regulation techniques. Self-regulation skills for the maintenance of a chronic illness may require different goals and strategies than self-regulation skills for health promotion.

**Ecological Systems Theory**

Bronfenbrenner's (1979) Ecological Systems Theory proposes that behaviors are shaped through complex reciprocal interactions from multiple environments. The interplay of these environments can promote the development of positive or negative health behaviors. For any health behavior, a comprehensive approach to prevention requires consideration of multiple levels (i.e. biological, individual factors, cultural factors) that influence health behaviors and the interactions among them (Smith, Orleans, & Jenkins, 2004). At the lowest level of Bronfenbrenner's ecological system theory are

Microsystems characterized by patterns of activities, social roles, or interpersonal relationships that directly interact with and affect the individual. Examples include interactions within the family, relationships at school, within the peer group, and community efforts to provide a health promoting environment. For instance, parents can provide transportation to be physically active, peers may participate in sports activities, and the community could provide additional opportunities to be physically active. Mesosystems on the other hand are comprised of the linkage between two or more microsystems where interactions between two microsystems can occur outside the presence of the child; as is evident in parent-teacher conferences or an intervention that links home and school curriculum. The exosystem does not require direct interactions with the child. Common examples include media or public policy that promote physical activity but do not target the child directly (Bronfenbrenner, 1994).

An ecological approach to behavior change is consistent with the perspective that the development of health behaviors are multifaceted and dynamic, and are developed in a social context through personal, interpersonal, and environmental interactions (Wilson & Lawman, 2009). Health behaviors are dynamic in that they are constantly changing and can be influenced by a number of factors including peer influence, school curriculum and parental relationships. Factors that are known to impact development of health behaviors include genetics, the family system, environmental factors, and societal and cultural influences (Wilson & Lawman, 2009).

To follow from the health behavior theories in the literature that various systems are vital to better understanding physical activity patterns; the following sections of the review will provide evidence for the influence of these various systems on physical activity. As mentioned previously, a number of systems have been researched, however a comprehensive review is beyond the scope of the paper. The microsystems that include parents, peers, and healthcare providers as well as exosystems, specifically mobile health technology will be reviewed in detail as these systems are relevant for the current study.

**Parental Microsystem**

Researchers are beginning to extend health promotion to incorporate specific ecological systems for changing health behaviors. Physical activity health behaviors in particular have been well documented to be influenced by multiple ecological systems (e.g. Cushing, Branon, Suorsa, & Wilson, 2014). The family is the primary context in which individual health behaviors are modeled, developed, and refined. Families provide an opportunity to significantly increase physical activity by means of engagement in activity, encouragement, and support.

Parental physical activity specifically has been consistently examined as a possible correlate to children and adolescents' physical activity (Gustafson & Rhodes, 2006). This review reported on 24 studies that examined the relationship between parental physical activity and child and adolescent physical activity, with mixed results. In one study using objective measures, children from families in which both parents were physically active were six times more likely to be active than children from families in which neither parent was active (Moore et al., 1991).

One potentially modifiable correlate of physical activity is parental social support which can be targeted directly by interventions and has proven to impact physical activity in children and adolescents. Greaves and colleagues (2011) conducted a systematic review of reviews that reported that the use of social support, usually from family members, provided an additional weight loss of 3.0 kg than interventions that did not incorporate social support. These results are consistent with examinations of social support for physical activity in children and adolescents. Gustafson & Rhodes (2006) conducted a review to synthesize the research on the impact of parental variables on physical activity level. The studies within the review suggested a strong positive correlation between parental support and child physical activity level (e.g. Van der Horts et al., 2007). A more granular analysis indicates that these results may differ by sample age and gender.

Specific correlates of physical activity have been examined in children and adolescents independently. Evidence suggests a positive link between parental physical activity and school-aged boys' physical activity, but not for girls' physical activity or adolescents' physical activity (Anderssen & Wold, 1992; Sallis et al., 1992). Notably, this effect appears to be more pronounced for younger children than adolescents (Garcia et al., 1995; Sallis et al., 1992). The vital forms of parental support included encouragement, involvement, and facilitation (Gustafson & Rhodes, 2006). In the context of the current paper, encouragement may serve as a trigger for the initiation of self-regulatory behaviors. Children and adolescents may require additional prompting to self-monitor or may need additional instruction in setting feasible and realistic goals.

Overall, providing verbal encouragement for physical activity has produced mixed results (i.e. Sallis et al., 1992; Gustafson & Rhodes, 2006) yet instrumental forms of support such as transportation to activities and actively playing with children significantly increase physical activity in children and adolescents (Sallis et al., 1992).

Providing direct feedback on goal attainment as opposed to verbal encouragement as a mechanism of social support has yet to be examined.

**Peer Microsystem**

As children move towards more autonomous behavior in adolescence they spend more time with peers who also become influential. Peer interaction and influence on physical activity has been examined in the context of mentorship (Smith, 2010; Black et al., 2010), through the use of peer support (Beets et al., 2006), as well as within common motivators of peer acceptance and increased friendship quality (Fitzgerald et al., 2012) as demonstrated below. One pilot intervention, in particular, involved teen mentors who provided support through the use of didactic and experiential methods like role-play to assist their mentee (peer) in physical activity engagement and healthy eating choices (Smith, 2010). Teen mentors delivered the intervention which incorporated reinforcement, goal-setting, self-monitoring, and planning ahead. The intervention not only improved on knowledge, intentions, and self-efficacy, but also produced a significant reduction in BMI. An additional study incorporated college-age peers trained in motivational interviewing to promote engagement in physical activity and increased fruit and vegetable consumption (Black et al., 2010). The Challenge! Intervention incorporated the use of role modeling and support via mentorship, participatory learning, goal-setting, barrier identification, and goal analysis. Peer mentors were instrumental in coaching participants during weekly challenges, and utilizing motivational interviewing skills to develop realistic goals by overcoming barriers. The intervention produced significant changes in body composition, reduction in weight status, and increased physical activity.

Adolescents with physically active peers reported higher levels of physical activity. Peer encouragement to be physical active included joining a sports team with a peer, or asking a peer to be active with the participant (Voorhees et al., 2005). Similar studies have examined the type of support received from peers including encouragement to do physical activity, watching take part in physical activity, talking about physical activity, and providing transportation for physical activity, with the greatest impact coming from peers who support and watch the target child participate (Duncan et al., 2005). These same types of support have been examined in both peers and parents to identify which individual confers the greatest effect on physical activity behavior (Beets et al., 2006). Participants completed self-report measures of physical activity and social support from both parents, and peers. Types of support included encouragement, transportation, watching, praise, etc. Peers appeared to exert more influence on physical activity behaviors in adolescents than do parents (Beets et al., 2006). Emerging literature suggests that the influence of peers is greater for at-risk/overweight adolescents than low-risk youth. Peer interventions appear to be a potential mechanism for increasing physical activity in adolescents, particularly through the use of peer social support.

Peers appear to have significant influence on physical activity levels in children and adolescents. These results are most pronounced when the peer is the same age and is encouraging the targeted individual to participate in organized activities. However, as children move into adolescence they participate in fewer organized activities and may need additional support to be physically active. Further examination of peer influence via feedback and verbal encouragement in adolescents is warranted.

**Healthcare Microsystems**

There has been a paucity of research examining the influence of healthcare providers as integral members for increasing physical activity in children and adolescents. Saelens and colleagues (2002) conducted a study in the primary care setting for overweight adolescents. Intervention targets included the instruction and use of self-regulatory behavioral strategies such as self-monitoring, goal-setting, problem solving, stimulus control, etc. When compared to a single session physician counseling visit, participants in the intervention condition experienced a decrease in BMI z-scores compared to the control condition. However, there were no significant differences in groups on measures of dietary intake, energy intake, sedentary behavior, or physical activity. While this study produced small effects on weight-related outcomes and no effect on physical activity behaviors; the study did demonstrate an increase in behavioral skills among the intervention condition which was related to better weight outcomes.

A study that incorporated more structured feedback from the healthcare provider reported significant results on physical activity in adolescents (Patrick et al., 2001). Adolescents completed a computerized assessment examining disordered eating behaviors or limited engagement in physical activity. Adolescents then chose a target and set a goal for behavior change based on feedback from the computerized assessment. Physicians completed a counseling session with the adolescent to discuss if the goals were appropriate and realistic and provided motivational information related to the adolescents' personal health status. Adolescents then received extended intervention and follow-up via mail or telephone. Results suggest a significant improvement in fruit and vegetable intake, decreased fat intake, increased moderate physical activity and vigorous physical activity. The effectiveness of this intervention may be due in part to the increased feedback in goal-setting from the physician counseling session.

### Exosystem Interventions

The exosystem level includes interventions that do not directly intervene one-on-one with individuals but still impact health behaviors. One novel intervention mechanism in the literature is the use of mobile health or other ubiquitous technology (i.e. internet, PDAs, etc.) to impact health behaviors in children and adolescents. Mobile devices are well suited to act as an exosystem intervention to support health behavior change because they can intervene at the right time, in the right context and in a convenient way because they are always turned on (Gasser et al., 2006). With the advancement of sensing technology, promise of personalized interventions, and ecological momentary assessment; mobile health interventions are well-poised to expand the health care realm to incorporate contextual factors that impact health behavior change.

### Mobile Health Interventions

The research on mobile health interventions represents a range of interactivity from basic informational text messages, real-time tracking of physical activity and dietary behaviors, to the use of mobile health apps that provide real-time feedback. Regardless of the intervention component, a recent systematic review suggested the efficacy and potential use of mobile technology for health promotion (Bert et al., 2013). Of the physical activity studies identified, seven reported significant results based on at least one outcome of weight loss or activity behavior (e.g. BMI, waist circumference, screen time). Some studies report that the mere use of a personal electronic device increases adherence to self-monitoring (Cushing et al., 2011), which has been demonstrated as an effective strategy in health behavior change (Wadden & Sarwer, 1999). A similar study reported the benefit of a mobile health device that is carried daily compared to a web-based intervention. Gasser and colleagues (2006), instructed participants to self-monitor via a mobile device or a web-based application. Results indicated that more than 50% of all behaviors were reported within the same hour when using a smartphone, whereas 30% of the behaviors had a 12 hour delay of reporting with a web-based application (Gasser et al., 2006). These results demonstrate that the self-monitoring component of cybernetic control theory can be greatly enhanced by incorporating the use of an “on the go” method of assessment such as a mobile device. Basic adherence to self-monitoring on smartphones has also produced significant weight loss in adults (Burke, Wang, & Sevick, 2011).

### Text Message Interventions

Additional studies have employed the use of short message service (SMS) text messages as a method of intervention delivery. The delivery of informational messages regarding diet, physical activity, and behavior modification led to significant reductions in weight, waist circumference, and BMI in healthy adults (Joo & Kim, 2007). Steinberg, Levine, Askew, Foley, & Bennett (2013) developed an intervention for overweight/obese Black women to assess the effectiveness of text messaging for self-monitoring and self-regulation. Behavioral goals were determined based on an algorithm developed by the interactive obesity treatment approach (iOTA) with additional skills instruction delivered via videos. Participants received weekly feedback on goal attainment. Approximately half of the participants were fully compliant to daily self-monitoring through the use of text messages. Similar results have been reported in samples of overweight children completing a cognitive-behavioral group (CBT) for weight loss (Bauer, de Niet, Timman, & Kordy, 2010). Upon completion of a 12-week CBT group, children were instructed to send weekly self-monitoring data on their eating and exercise behavior, and subsequently receive tailored feedback via text messages from the study staff. Children submitted 67% of the weekly SMS they were expected to send and experienced a significant reduction in BMI status.

Reviews of the mobile health literature have provided mixed results as some argue that text messaging interventions used as adjuncts to additional intervention components (i.e. group discussion, education) are effective, whereas, the effectiveness of mobile technology as stand-alone interventions is inconclusive due to the small sample size (Stephens & Allen, 2013). Specifically, the extant literature includes the use of text messages as adjuncts to larger intervention trials including support for a specific weight management program, supported by education, or telephone calls from study staff. Few studies to date have used mobile health technology as a stand-alone intervention; therefore the effectiveness of this approach has yet to be determined.

**Mobile Health Application Interventions**

To capitalize on the increased interactivity of mobile health technology, mobile health apps have been designed to serve as a method of intervention. Interventions that have incorporated a mobile app have produced mixed results. In one such intervention, the app recorded exercise, daily consumption and showed progress towards meeting daily goals. The authors reported significant decreases in weight related outcomes including fat mass, weight, and BMI in adults compared to participants using a web-based application (Gasser et al., 2006). The second app provided a more competitive environment in which the adult participant was a member of a team. The application provided results for the other team, sent messages and reminders, and was used as a mechanism for answering questionnaires. This intervention, however, produced no significant differences among the intervention and control participants (Lee et al., 2010). These two mobile health interventions as stand-alone had sample sizes of 36 and 40, respectively, which may diminish the generalizability and effectiveness of the results (Gasser et al., 2006; Lee, Chae, Kim, Ho, & Choi, 2010).

Carter and colleagues (2013) developed a mobile health app called My Meal Mate (MMM) for adults that combines the capabilities of self-monitoring with feedback via text messages to assess the use of an app as a stand-alone intervention. Results from a pilot trial (N = 128) reported a significant difference in follow-up weight between the three arms (smartphone app, diary group, website group). This study provides preliminary support for the efficacy of a mobile health app as a method of intervention delivery for weight-related outcomes.

Apps have also been incorporated into multi-component programs to assist in weight management for young adults (Hebden et al., 2013). Participants met with a dietician and set goals to address two behaviors (fruit and vegetable intake, sugar-sweetened beverages, physical activity, energy dense foods). The program included a booklet to detail national physical activity and energy intake goals as well as example meal plans. Participants were also provided two SMS text messages and emails each week (based on the Transtheoretical Model) while also provided access to a mobile health app and internet discussion forum. However, there was no evidence of an effect of the mobile intervention on body weight or BMI. The authors contribute this to the lack of engagement with the program as a number of participants in the intervention group did not use the mobile health app or the internet discussion forum. Participants in both conditions did lose significant weight, which may lend itself to the dietary and nutrition counseling as the driver of the effect in this intervention. Feedback from participants indicated that a more personalized approach, including personalized goals and daily tracking, to the SMS text messages would have been more beneficial. Potential hypotheses for limited engagement may include difficulties with the functionality of the technology, limited time to log-on, or the influence of multiple modalities of intervention may have been barriers to engagement. However to combat issues of disengagement, the current study will utilize a single mobile health app developed by technology experts that will provide personalized prompts. Additionally, the use of social support to engage in self-regulation may also increase engagement with the app.

**Mechanisms of Behavior Change**

It has been suggested that the lack of effectiveness of physical activity interventions is due to a lack of understanding of the agents of behavior change (Baranowski & Jago, 2005). While interventions are typically developed based on theoretical frameworks of behavior change (i.e., Social Cognitive Theory, Theory of Planned Behavior), very few studies have looked at the mechanisms of change in physical activity interventions. Given the interest in identifying the components that work in promoting physical activity in children and adolescents, studies have begun to examine the direct effect of interventions on mediators. Lubans, Foster, and Biddle (2008) conducted a review and identified seven studies that evaluated cognitive mediators (i.e. self-efficacy, outcome expectancy, perceived barriers), behavioral mediators (i.e. goal-setting), and interpersonal mediators (i.e. interpersonal norms, social support). The cognitive mediators of self-efficacy and outcome expectancy were found to influence changes in physical activity. However, perceived barriers provided mixed results in terms of the relationship to physical activity. Only two of the studies assessed behavioral mediators, where one intervention had a significant effect on goal-setting, yet the changes were not related to physical activity. Lastly, interpersonal mediators of social support or exposure to models did not prove to predict changes in physical activity, which is inconsistent with previous reports indicating the effectiveness of social support (e.g. Beets et al., 2006; Van der Horts et al., 2007). Similar studies have examined the mechanisms of change among adherence interventions and report that interventions that incorporate behavioral strategies (i.e. self-monitoring, goal-setting) are more effective than studies that do not include these types of strategies (Kahana, Drotar, & Frazier, 2008). The most effective interventions were multi-component interventions that incorporated both education and behavioral strategies.

Brannon and Cushing (under review) systematically reviewed the child and adolescent literature to identify the mechanisms of change in health promotion interventions for physical activity and diet. The authors employed the published behavior change taxonomy developed by Abraham and Michie (2008) to identify the specific components that drive the effectiveness of behavioral interventions. The results indicated that the meaningful behavior change techniques differed from those identified in the adult literature, and also differed according to the individual's age and the targeted behavior.

For instance, modeling and social support was a significant predictor of dietary study effect size for children, with modeling also producing positive effects in terms of physical activity interventions. Whereas, modeling, social support, consequences, information on other's approval, self-monitoring, intention formation, and behavioral contracts were positive predictors of study effect size in adolescents.

Rabin & Bock (2011) conducted a study in which participants provided qualitative feedback on three mobile health apps to determine the feature most desired by participants. They emphasized the importance of receiving feedback on accomplishments, and that the app should accommodate different forms of physical activity. Others argued that a goal-setting feature and problem-solving feature was also listed as a desirable for participants. Collectively, exosystem interventions specifically the use of mobile health has provided preliminary support for increased physical activity in children, adolescents, and adults whether as an adjunct to a multi-component program or a stand-alone intervention. Additionally, examination of the specific components of interventions that drive the effectiveness may be more suitable for translation to the mobile health arena (Brannon & Cushing, *under review*). However, as technology continues to advance, the research examining the efficacy of these mobile health interventions as well as the specific components of interventions that can translate to mobile health is warranted.

Collectively, each level of Bronfenbrenner's Ecological Systems Theory has value for changing physical activity behaviors in children and adolescents. No study to date has experimentally examined which microsystem confers the greatest impact on physical activity behaviors. With the increased uptake of mobile health technology, and the technological capabilities of providing realtime interventions that allows for dynamic processes, mobile health apps are well poised to be a notable vehicle for health behavior change.  As the review indicates, there are notable difficulties in changing health behaviors in adolescents, as they spend more time away from parents and interact more with peers. Additionally, the literature reviewed suggests that parental support is more influential in young children compared to adolescents. The current study will experimentally examine the impact of parent, peer, and support from a healthcare professional has on adolescents physical activity. Adolescents will also be asked to use a mobile health app to set goals, self-monitor and review their progress. Previous studies have reported low engagement with the use of an internet app, however, this could be a result of the complexity of the intervention as the participants received nutrition counseling, text messages, emails, discussion forums, and an internet application. The current project will be limited to the use of a mobile health app that is commercially available, and interacts with social networking. Additionally, recent statistics estimate that adolescents spend 7 ½ hours per day consuming media, typically on their cell phones (PEW Statistics, 2010). Due to the increased usage of smartphone usage among adolescents, it is expected that there will be high engagement with the mobile health app.

**Current Study**

The current study seeks to address the gaps in the literature by examining the effectiveness of intervening at differing systems levels for increasing physical activity among adolescents. The study will experimentally test which microsystem level (e.g. parent, peer, behavioral health specialist) will produce the greatest increase in physical activity among sedentary adolescents. This study will be the first study to my knowledge to also incorporate the use of a mobile health app, with strategies consistent with control theory in addition to personalized feedback from members at each systems level. It is hypothesized that support from peers will significantly increase the amount of physical activity engagement. The second hypothesis is that parent influence will produce increased levels of physical activity compared to the influence of the healthcare professional. Lastly, it is expected that all three intervention levels (i.e. peer, parent, and healthcare professional) will significantly increase physical activity compared to the app alone, or control condition.

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