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Adding Family Digital Supports to Classroom-Based Physical Activity Interventions to Target In- and Out-of-School Activity: An Evaluation of the Stay Active Intervention during the COVID-19 Pandemic

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Abstract

Remotely delivered interventions are promising for reaching large numbers of people, though few have targeted multiple levels of influence such as schools and families. This study evaluated two versions (arms) of a remotely delivered classroom-based physical activity (CBPA) intervention. One arm solely included remote CBPA; the other included remote CBPA and mobile health (mHealth) family supports. Six schools were randomized to CBPA or CBPA+Family. Both arms were remotely delivered for seven weeks. CBPA+Family added behavior change tools delivered via text messages and newsletters to caregiver/child dyads. Garmin devices measured moderate-to-vigorous activity (MVPA) in both arms and were used for goal setting/ monitoring in the CBPA+Family arm (integrated with the text messages). Caregivers completed surveys evaluating intervention acceptability. 53 participants (CBPA n=35; CBPA+Family n=18; 9.7±0.7 years) were included. Increases in MVPA were similar between arms, showing a pre-post effect of the CBPA but no additional effect of family supports. MVPA was low at baseline and during the first 3 weeks (CBPA 7.5±3.1 minutes/day; CBPA+Family 7.9±2.7 minutes/day) and increased by Weeks 6-8 (CBPA 56.8±34.2 minutes/day; CBPA+Family 49.2±18.7 minutes/day). Approximately 90% of caregivers reported high satisfaction with the added family support content. CBPA+Family participants wore the Garmin later into the study period. Remote delivery of CBPA appears feasible and effective for supporting increases in children's MVPA. Adding family supports to school-based interventions appears acceptable and may support engagement, demonstrating promise for more multilevel/multi-setting interventions, though the multilevel intervention was not more effective than the single-level intervention in increasing children's MVPA.

Keywords*:* mHealth, mobile health, short messaging system (SMS), pediatric, school, wearables

Physical activity improves the cognitive, physical, and mental health of children (Dale, Vanderloo, Moore, & Faulkner, 2019; Janssen & Leblanc, 2010; Poitras et al., 2016). However, 72.2% of children ages 6-11 years in the United States have insufficient levels of activity to achieve these benefits (Friel, Duran, Shechter, & Diaz, 2020). Thus, it is a public health priority to develop interventions that can increase physical activity in children.

Many activity interventions for children target either the school or home setting due to the large amount of time spent in each location (Metcalf, Henley, & Wilkin, 2012). Children generally accumulate one third to half of their total daily physical activity at school (Carlson et al., 2016; Klinker, Schipperijn, Christian, Kerr, Ersbøll, & Troelsen, 2014; Ortega et al., 2020), but school-based physical activity can vary drastically across schools (Carlson et al., 2013; Tassitano, Weaver, Tenório, Brazendale, & Beets, 2020). School-based interventions, such as those targeting classroom-based physical activity (CBPA), have been effective for increasing physical activity during the school day (Carlson et al, 2015; Watson, Timperio, Brown, Best, K, & Hesketh, 2017). However, CBPA interventions have consistently had low uptake and implementation rates due to barriers faced by schools and teachers (Carlson, Engelberg, Cain, et al., 2015; Erwin, Beighle, Morgan, & Nolan, 2011). Thus, more research is needed on strategies for increasing their uptake and frequency of delivery. Additionally, since CBPA interventions target a single setting, they can have a limited impact on children's total daily activity, amounting to ~4 minutes/day of additional activity on average (Eisenmann et al., 2008; Watson et al., 2017). Targeting additional settings, including time outside of school, is likely needed to support larger increases in children's total daily activity and create a more multi-level approach (Eisenmann et al 2008; Messing et al., 2019; Salmon et al., 2007).

Advances in technology, paired with cultural shifts caused by the COVID-19 pandemic, have contributed to increased use of mobile and other digital technology that support remote interaction. These advancements create opportunities to deliver CBPA remotely to classrooms, which can simplify the classroom teacher's role by allowing an outside person/group to deliver the intervention efficiently. This also allows for outside individuals to deliver CBPA to multiple schools/classrooms at a time or within a day. Advances in technology also provide opportunities to support families through scalable mobile health (mHealth) (e.g., text messaging) interventions (Fedele, Cushing, Fritz, Amaro, & Ortega, 2017; Ludwig, Arthur, Sculthorpe, Fountain, & Buchan 2018; Militello, Kelly, & Melnyk, 2012), which could build upon single-setting (e.g., school-based) interventions. mHealth interventions have been successful in increasing children's physical activity across multiple studies (Cushing, Bejarano, Ortega, Sayre, Fedele, & Smyth, 2021; Fedele et al., 2017; Ludwig et al., 2018; Militello, Kelly, & Melnyk, 2012; Shapiro, Bauer, Hamer, Kordy, Ward, & Bulik, 2008). Previous research has also shown that child behavior improves more when the intervention includes caregivers (i.e., is family-based) rather than targeting only the child (Fedele et al., 2017; Militello, Kelly, & Melnyk, 2012). However, more research is needed on the feasibility, acceptability, and impact of integrating family mHealth interventions with school-based physical activity interventions.

Given that primary caregivers (e.g., parents, guardians) play an important role in supporting children's physical activity outside of school, numerous child interventions have aimed to incorporate caregivers (Norton, Froelicher, Waters, & Carrieri-Kohlman, 2003; Rhodes et al., 2020; Sallis, Prochaska, Taylor, 2000). Interventions that have integrated school- and family-based strategies have had positive impacts on physical activity (Christodoulos, Douda, Polykratis, et al 2006; Luepker, Perry, McKinlay, et al., 1996; Messing et al., 2019; Stevens, Story, Ring, Murray, Cornell & Gittelsohn, 2003; Van Sluijs, McMinn, & Griffin, 2007; Warren, Henry, Lightowler, et al., 2003). However, few interventions have integrated individualized family-based mHealth behavior change techniques (e.g., self-regulation) with school-based structured activity. mHealth is promising for providing family-based supports because it can be efficiently used to reach large numbers of people and provide individualized/tailored information to caregivers and their children (Direito, Carraça, Rawstorn, Whittaker, & Maddison; 2017).

The challenges faced by children and caregivers in low-income communities appeared to be exacerbated during COVID-19 pandemic, at least in part due to economic and logistical barriers and heightened levels of stress (e.g., working caregivers managing children's time and learning while also dealing with adaptations to their own work patterns) (Lam, Kandula & Shawman, 2021; Spinelli, Lionetti, Setti & Fasolo, 2020). Yet, caregiver support for their child's physical activity may have been especially important during this time, as peer support was often limited and the transition from in-person to remote learning eliminated a large portion of children's physical activity opportunities (Brazendale et al., 2017; Dunton, Do, & Wang, 2020). Thus, it became critical to mitigate the negative health impacts of the pandemic on children from low-income backgrounds, and to minimize the acceleration of existing health disparities (e.g., higher rates of obesity) (Chi, Luu & Chu, 2017).

The present study, Stay Active, delivered and evaluated an intervention designed to increase physical activity in children from low-income communities who were learning in fully remote classrooms (November and December 2020). This study included two arms; both involved the same remotely delivered CBPA intervention. The first arm, named 'CBPA', included only the remotely delivered CBPA. The second arm, named 'CBPA+Family', included the remotely delivered CBPA and added a family-based mHealth intervention to target physical activity more holistically across the day. The first study aim was to evaluate the feasibility and impact of the remote CBPA intervention on changes in children's physical activity over time (pre-post within arm comparison). The second aim was to evaluate whether the family-based mHealth component had an added benefit on physical activity and adherence to wearing the Garmin monitor, over and above the CBPA (between arm comparisons). Feasibility and acceptability of the intervention were also evaluated.

Methods

Participants and Procedures

The research team partnered with six schools in Kansas City, Missouri, USA. All schools were in low-income communities and had a free or reduced-price lunch eligibility rate of >99.0% prior to the pandemic (Elementary and Secondary Information System, 2020). All schools were engaged in fully remote learning (students and teachers) for Fall 2020, during the time of the study (November and December 2020). Only 4th and 5th grade classrooms were targeted and a total of 12 classroom teachers agreed to participate. All participants were caregiver/child dyads due to the potential of being randomized to the CBPA+Family arm and because study surveys were completed by the caregiver. Caregiver/child dyads were informed about the study via word-of-mouth and informational letters from participating classroom teachers. Eligibility criteria were that the caregiver was able to read and communicate in English, had access to a personal smart mobile device capable of running the Garmin Connect application, and agreed to receive study text messages. While all students in the classrooms were able to receive the CBPA, only eligible dyads were enrolled into the research study.

The six schools were randomized into the CBPA arm or CBPA+Family arm after a baseline period. In both arms, child participants were asked to wear a Garmin physical activity monitor (Vivofit 4; Garmin International, Inc., USA) for a nine-week period comprising one baseline week (Week 0), the 7-week intervention period, and one week immediately following the intervention (Week 8). Caregivers were asked to complete a demographic survey at baseline and a program acceptability survey immediately following the intervention. Dyads received $50 for participating in the study. The study was approved by the local Institutional Review Board, and caregivers and children provided consent and assent, respectively, prior to data collection. The study is registered at ClinicalTrials.gov (NCT04675658).

Intervention Arms

CBPA

The CBPA lessons were informed by and adopted from established programs with age-appropriate content for our target sample (e.g., Classroom Physical Activity Ideas and Tips, 2020; GoNoodle, 2015; Sanford Health, 2021). Each lesson lasted ~10 minutes, and delivery occurred twice a week for seven weeks. Lessons were designed to get children moving and included activities such as yoga, kickboxing, tabata-style workouts, and weight training (with household items). The lessons were delivered via live video conferencing and led by trained physical activity leaders employed by the research team. This approach of having the research team deliver the CBPA was selected to support consistent implementation and minimize teacher burden given the numerous challenges teachers faced due to remote learning.

CBPA+Family

Participants received the same classroom physical activity lessons as the CBPA arm participants, plus additional family-based content to promote behavior change, including text message content and newsletters. The content was informed by evidence-based behavior change techniques, including self-regulation (monitoring and feedback), goal setting, barrier identification and problem solving, and motivation (Michie, Abraham, Whittington, McAteer, & Gupta, 2009). Text messages were sent to the caregiver up to four times each week, centered on the child's step count data collected from the Garmin, and framed to encourage caregiver and child interaction around the message content. A daily step count goal was set by the Garmin using an adaptive algorithm that increases or decreases the goal based on the child's accomplishments over the previous days (Garmin Ltd., 2018). The first text message of the week was sent on Sundays and contained either congratulatory content (if goals met for ≥ 4 days in the past week) or encouraging content to promote goal attainment (if goals met for < 4 days in the past week). Each encouragement message introduced a new behavior change technique (e.g., 'Try problem-solving to see what's getting in the way and figure out how to overcome these barriers!'). The second text message, sent on Mondays, conveyed achievements from steps taken since the start of the intervention (e.g., 'Wow! [child's name] has walked the distance of FIVE marathons!'). A third message was sent on Wednesdays if the child had not met their step goal on ≥ 1 of the first 3 days that week, with a new encouragement message and behavior change tip. The last message each week was sent on Fridays and linked to a weekly 2-page online newsletter. Newsletter content included a weekly behavior change topic that paralleled the content of the encouragement messages (e.g., goal setting, barrier identification and problem solving), activity ideas for the family to engage in together, and activity ideas for the child to perform throughout the day.

Measures

Garmin Vivofit 4

The Garmin Vivofit 4 is a wrist worn commercial device that provides estimates of steps and active minutes (a proxy for moderate-to-vigorous physical activity, MVPA). All children in the study (both intervention arms) were asked to wear the Garmin every day throughout the intervention period. At the start of the intervention, study staff helped each dyad set up a Garmin Connect account on their smart device to facilitate automatic transfer of data into the Garmin application programming interface (API). The study team then retrieved the data through the API. In the CBPA arm, the devices were used only for measurement purposes (not for intervention, e.g., text messages). In the CBPA+Family arm, the Garmin devices were used for both measurement and intervention, including integrating the step count data and daily step goal accomplishments with the text message content. To support measurement efforts by the research staff, caregivers in both intervention arms were also sent text messages to remind their child to wear and/or sync the Garmin monitor with the Garmin Connect app if data were not recorded on ≥3 days during the week (e.g., 'We haven't seen any activity on [child's name]'s Garmin in the past few days. Please make sure your child is wearing and syncing the device').

Physical activity metrics (steps/day and MVPA minutes/day) were examined 1) for school hours and 2) across the entire day. A variety of analyses were completed as described below, some that involved averaging daily values into week-level values and others that involved averages over longer time periods. 15-minute epochs with a maximum motion intensity of zero, indicating no movement of the watch, were considered non-wear. Days were excluded if they had < 8 hours of wear time or < 100 total steps. Daily steps were also screened for implausible values and excluded if there were > 20,000 total steps, > 10,000 in-school steps, > 5 hours of total MVPA, or > 2.5 hours of in-school MVPA in a single day, based on examination of outliers.

Demographic Surveys

Demographic Surveys were completed by caregivers at baseline. The survey contained questions about sociodemographic characteristics (e.g., household income, race/ethnicity) and child anthropometrics (i.e., height and weight).

Program Acceptability Surveys

Program Acceptability Surveys were completed by caregivers after the intervention. Caregivers completed seven items asking how acceptable they and their child found the intervention. Families in the CBPA+Family arm completed an additional seven items asking how acceptable they found the text messaging and newsletter components. All survey responses were given on a 4-point Likert type scale (1 = strongly disagree, 4= strongly agree), and three open ended questions were included to allow for additional feedback (i.e., What did your child like most about the Stay Active Program?; What are your suggestions for improving the Stay Active program?; What did and/or did not you and your child like about the newsletters and text messages?).

Data and Statistical Analyses

Data were analyzed using SPSS (version 27.0, SPSS Inc.) and R (version 4.0.5) (R Core Team, 2021). Descriptive statistics were used to summarize family demographic characteristics and post-intervention acceptability data. Qualitative data from the open-ended questions on the post-intervention survey were reviewed by two researchers independently who then met to prepare a summary of the content and select representative quotes.

The analyses of the Garmin data aimed to compare the intervention arms in terms of adherence to wearing the Garmin device (as proxy for intervention engagement) and assess both pre-post and between-group differences in physical activity (steps and MVPA, in and out of school). For the adherence analyses, we examined each participant's number of weeks with ≥ 1 valid wear day starting with the first week of the intervention (week 1 – week 8) and when the last valid wear day occurred. For the physical activity analyses, several modeling approaches were explored that differed in their time resolution and approach to handling missing data. The purpose of using multiple approaches was to understand the influence of missingness on the study's findings, given a small sample size. All approaches shared the following characteristics: 1) mixed effects modeling to account for the clustering of time points within participants; 2) adjustment for participant sex, number of wear days at each time point, and proportion of data from weekend days; and 3) testing for a main effect of time and a time X arm interaction. The models did not account for the nesting of participants within schools or classrooms because models would not converge when these parameters were included.

The first three modeling approaches used week-level data from all nine assessment weeks. These models included all participants who provided ≥ 1 valid day of data at any point after the first week of the intervention and ≥ 3 valid days total over the 9-week study duration. A 'Standard' model was fitted to the non-missing data using restricted maximum likelihood estimation. An 'LVCF' model was fitted using last-value-carried-forward. This approach assumed the participant's activity during missing weeks was the same as during the most recent non-missing week. Missing data at the beginning of the study were similarly filled in using the participant's earliest non-missing data. A 'JM' model was fitted using joint modeling, which combines the mixed effects model with a survival model predicting time to last wear day (Rizopoulos, 2010). The latter component was a Cox proportional hazards model where time to last wear day was modeled as a function of school, sex, and the median and inter-quartile range of week-to-week physical activity metrics within each participant. The JM approach was implemented to address the potential that less active individuals were systematically more likely to stop wearing the device earlier than more active individuals.

The final modeling approach involved grouping weeks into two time periods: early intervention (Weeks 0-3, i.e., baseline and first 3 weeks of intervention) and late intervention (Weeks 5-8, i.e., final 3 weeks of intervention, and one-week post-intervention]). One value for the early time point and one for the late period were computed for each participant by averaging across all their valid wear days for the time point. Participants were excluded if they did not have a value for both time periods.

Results

A total of 216 students were enrolled in the classrooms that participated in the intervention and received the CBPA lessons. Fifty-nine families expressed interest in participating in the research study (receiving the Garmin and receiving the family intervention if their classroom was randomized into the CBPA+Family arm). Four of these families were ineligible and two chose to not participate after expressing initial interest. Ultimately, 53 families consented to the study; no families withdrew after enrolling. Families were not blinded to their study arm. Forty families responded to the demographic survey (75.5% response rate). Demographic characteristics of these children and caregivers are shown in Table 1. Three schools were randomized to the CBPA arm, comprising six classrooms and 35 participating caregiver/child dyads from a total of 115 possible students. The other three schools were randomized to the CBPA+Family arm, comprising six classrooms and 18 participating caregiver/child dyads from a total of 101 possible students.

Table 1. Caregiver reported demographic characteristics of study participants.

	CBPA	CBPA+ Family
Enrolled n (%)	35 (66.0%)	18 (34.0%)
Responded to baseline survey n (%)	26 (74.2%)	14 (77.7%)
Child Demographics		
Age (years)	9.7 (0.7)	9.6 (0.8)
Weight (kg)	41.2 (12.8)	41.9 (13.2)
Height (cm)	141.7 (13.2)	141.0 (17.3)
Body Mass Index ($kg{\cdot}m^{-2}$)	21.6 (6.0)	21.2 (7.0)
Body mass index percentile (%)	74.7 (28.8)	69.3 (39.1)
Female n (%)	18 (69.2%)	8 (57.1%)
Race n (%)		
Asian	3 (11.5%)	1 (7.1%)
Black	14 (53.8%)	9 (64.3%)
Hispanic / Latinx	4 (15.4%)	1 (7.1%)
Multiracial	-	1 (7.1%)
Native American, Native Hawaiian, or Alaska Native	1 (3.8%)	-
White, non-Hispanic/Latinx	2 (7.7%)	1 (7.1%)
Refused to answer	2 (7.7%)	1 (7.1%)

Caregiver/Family Demographics		
Female n (%)	23 (88.5%)	14 (100.0%)
Marital status n (%)		
Never married	10 (38.5%)	9 (64.3%)
Married	13 (50.0%)	5 (35.7%)
Divorced	3 (11.5%)	-
Annual income n (%)		
<$30,000	11 (42.3%)	9 (64.3%)
≥$30,000	15 (57.7%)	5 (35.7%)
Highest level of education n (%)		
High school or less	6 (23.1%)	8 (57.1%)
Some college / university	4 (15.4%)	2 (14.3%)
College / University degree	16 (61.5%)	4 (28.6%)

Note. Except where otherwise noted, values are mean (SD); CBPA = classroom-based physical activity; SD = standard deviation.

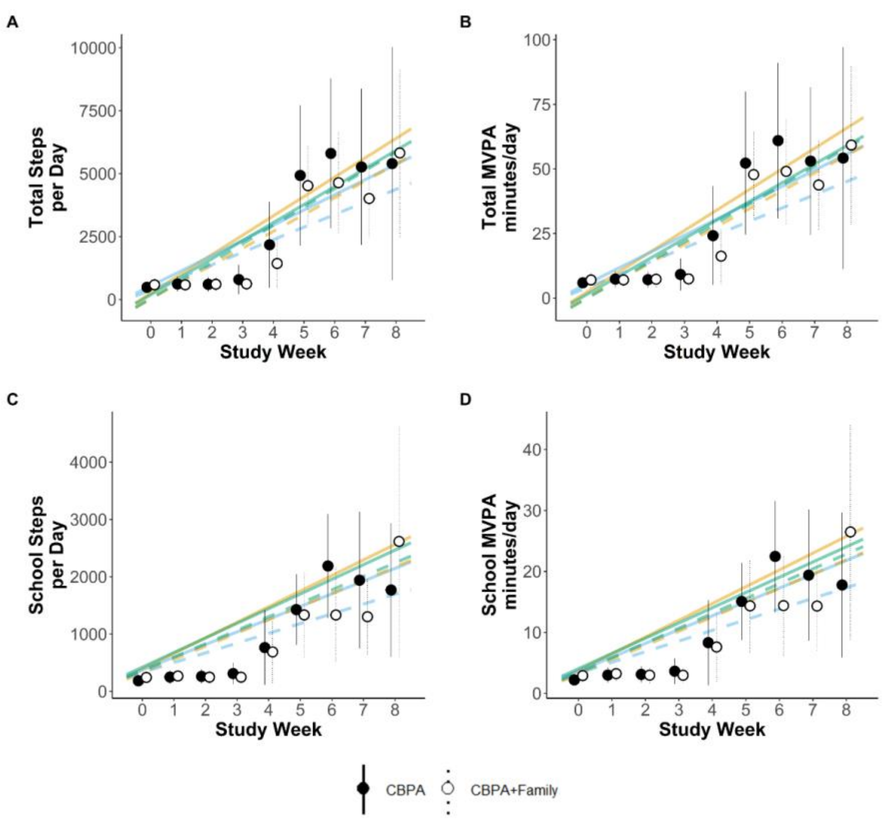
Changes in physical activity

Of the 53 participants enrolled in the study, 32 provided ≥1 valid day of physical activity data throughout the study duration (CBPA n = 14 out of 35 [40%]; CBPA+Family n = 18 out of 18 [100%]). Out of 1202 days that met the minimum wear time and step thresholds, two were excluded for implausible values. These were consecutive weekdays for a single participant, occurring in Week 8 (one-week post intervention).

Analyses of the week-level data included 28 participants (CBPA n = 12; CBPA+Family n = 16). Three of the four excluded participants had no valid data past the first week of the intervention, and the other participant had < 3 total days of valid data for the study duration. Figure 1 and Table 2 present the results of the three modelling approaches. All models showed statistically significant ($p < .05$) and meaningful increases in activity over time, regardless of intervention arm. No models produced a statistically significant or meaningful interaction effect between time and arm, indicating that children's physical activity increased at a similar magnitude within each study arm (the difference between arms was approximately 1 minute/day for total MVPA). Children's activity first increased at Week 3 and generally continued to increase until the end of the study. The three modeling approaches exhibited similar results, with the last value carried forward models providing the most conservative estimate of changes in activity over time.

Figure 1

Physical Activity Metrics across Study Weeks for each Intervention Arm (n = 28)



Note. Circles show observed means and vertical lines show standard deviations across participants. Slopes for the CBPA arm shown using solid regression lines and slopes for the CBPA+Family arm shown using dashed regression lines. Orange regression lines are from standard mixed effects models, blue regression lines are from models with last value carried forward and back-fill, and green regression lines are from joint modeling. CBPA = classroom-based physical activity; MVPA = moderate to vigorous physical activity.

Table 2. Modeling results for physical activity metrics across intervention weeks (n = 28).

	B (95% CI)		
Outcome variable	Standard	LVCF	JM
Total steps/day			
Intercept	248.5 (-669.8, 1137.)	537.9 (-83.7, 1151.4)	189.9 (-774.7, 1154.5)
Time[a]	768.8 (485.0, 1045.3)	603.8 (325.2, 882.0)	716.6 (564.4, 868.7)
Time*Arm[b]	-100.1 (-470.0, 268.9)	-104.8 (-472.0, 262.5)	11.1 (-193.5, 215.6)
Total MVPA minutes/day			
Intercept	2.3 (-6.8, 11.1)	5.4 (-0.8, 11.5)	1.4 (-8.9, 11.6)
Time[a]	8.0 (5., 10.8)	6.3 (3.5, 9.1)	7.2 (5.6, 8.8)
Time*Arm[b]	-1.1 (-4.8, 2.7)	-1.1 (-4.9, 2.6)	0.1 (-2.1, 2.3)
School steps/day			
Intercept	389.7 (-3.4, 773.0)	373.5 (109.0, 635.1)	421.4 (26.3, 816.6)
Time[a]	272.0 (166.7, 375.4)	221.6 (120.8, 322.3)	255.6 (195.2, 315.9)
Time*Arm[b]	-41.4 (-179.4, 95.6)	-51.2 (-184.0, 81.6)	-20.3 (-100.5, 59.9)
School MVPA minutes/day			
Intercept	3.7 (0.0, 7.3)	3.7 (1.2, 6.1)	4.0 (0.2, 8.0)
Time[a]	2.8 (1.7, 3.8)	2.3 (1.3, 3.3)	2.5 (1.9, 3.1)
Time*Arm[b]	-0.4 (-1.8, 1.0)	-0.5 (-1.9, 0.8)	-0.1 (-0.9, 0.7)

Note. All models adjusted for participant sex, number of wear days at each time point, and proportion of data from weekend days.
Standard = no extra adjustment for missingness; LVCF = last value carried forward, with back-fill; JM = joint modeling; B = unstandardized regression coefficient; CI = confidence interval; MVPA = moderate to vigorous physical activity
[a]Weeks since start of intervention (range from -1 (baseline) to 7 (Week 8, 1 week post intervention); intercept corresponds to activity in the first intervention week)
[b]0 = CBPA [classroom-based physical activity]; 1 = CBPA+Family

The analyses comparing early versus late intervention (two time periods) included 10 participants from the CBPA arm and 11 from the CBPA+Family arm. The additional 7 participants excluded had no data in the late intervention time period. Figure 2 summarizes participant-level data and Table 3 provides group-level descriptive statistics and model results. Similar to the week-level models, all models had a statistically significant and meaningful main effect for time, showing increases in MVPA minutes/day and steps/day, in school and out of school. There were also no statistically significant or meaningful interaction effects between time and arm. Within each arm, total daily activity in the early time point was low (7.5-7.9 minutes/day of MVPA and 637-663 steps/day), with almost half of the activity occurring during school hours (2.8-3.3 minutes/day of MVPA and 239-274 steps/day). In the late time point, total daily MVPA increased by 41.3-44.2 minutes/day, with about 30% of the increase in each group (12.8-14.7 minutes/day) occurring during school hours.

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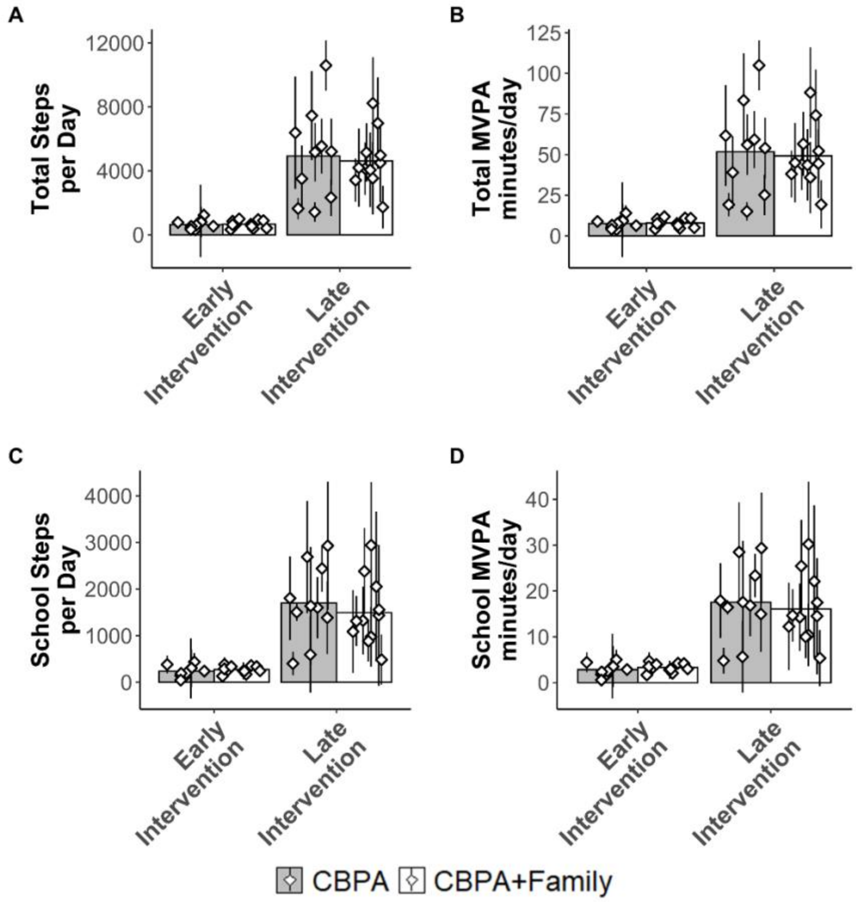
Figure 2

Physical Activity Metrics Grouped by Early and Late Intervention and Intervention Arm (n = 21)



Note. Jittered dots are participant means for each time point, and error bars represent ±1 standard deviation across days within participants. Bars are observed grand means. CBPA = classroom-based physical activity; MVPA = moderate to vigorous physical activity; Early intervention = Week 0 (baseline) and Weeks 1 to 3 (first 3 weeks of the intervention); Late intervention = Weeks 5 to 8 (final 3 weeks of the intervention and 1-week post-intervention).

Table 3. Modeling results for physical activity metrics from early to late intervention.

	Observed Mean ± SD		B (95% CI)[a]	
	CBPA (n = 10)	CBPA+Family (n = 11)	Time	Time*Arm interaction
Total steps/day				
Early intervention	637.0 ± 281.3	662.7 ± 234.8		
Late intervention	4923.9 ± 2846.0	4625.0 ± 1752.8	4285.3 (2915.1, 5655.5)	-318.8 (-2202.2, 1564.7)
Total MVPA minutes/day				
Early intervention	7.5 ± 3.1	7.9 ± 2.7		
Late intervention	51.8 ± 28.5	49.2 ± 18.7	44.33 (30.3, 58.3)	-2.97 (-22.2, 16.2)
School steps/day				
Early intervention	239.1 ± 118.7	274.0 ± 78.2		
Late intervention	1698.7 ± 823.3	1493.9 ± 713.2	1463.8 (1010.3, 1917.3)	-243.3 (-865.8, 379.2)
School MVPA minutes/day				
Early intervention	2.8 ± 1.3	3.3 ± 0.9		
Late intervention	17.5 ± 8.2	16.1 ± 7.3	14.8 (10.2, 19.3)	-1.99 (-8.3, 4.3)

Note. CBPA = classroom-based physical activity; MVPA = moderate to vigorous physical activity; Early intervention = Week 0 (baseline) and Weeks 1 to 3 (first 3 weeks of the intervention); Late intervention = Weeks 5 to 8 (final 3 weeks of the intervention and 1-week post-intervention).
[a]Adjusted for participant sex, number of wear days at each time point, and proportion of data from weekend days at each time point.

Garmin Wear Adherence

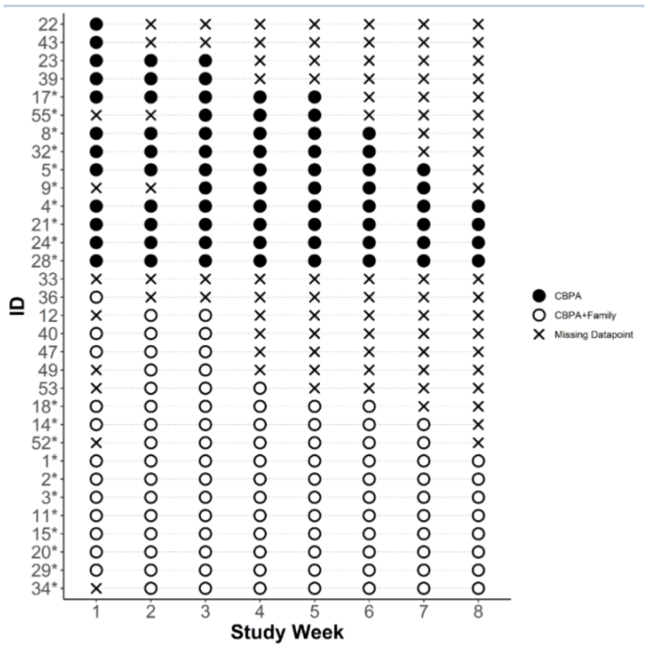
Among participants with ≥1 valid day of Garmin data between weeks 1-8 (baseline was excluded), the number of weeks with ≥ 1 valid wear day was similar between arms (CBPA 5.2 ± 2.5 weeks versus CBPA+Family 5.3 ± 2.9 weeks; out of 8 total weeks). Figure 3 shows individual adherence trends at the week level. In the CBPA arm, four participants (29%) had valid data during Week 8, compared to eight participants (44%) in the CBPA+Family arm.

Acceptability of the Interventions

Of the 53 participating dyads, 35 completed the program acceptability survey after the intervention. Of those, 25 were from the CBPA arm (71.4% response rate) and 10 were from the CBPA+Family arm (55.6% response rate). Participant ratings on questions relating to acceptability of the CBPA lessons and Garmin monitor were similar between arms (Table 4). The majority (94.3%) of caregivers agreed or strongly agreed they were satisfied with the overall quality of the Stay Active program. Most caregivers (94.2%) reported their child was satisfied with the physical activity lessons. 94.3% of caregivers agreed or strongly agreed their child enjoyed using and wearing the Garmin, with 91.4% agreeing their child would continue to wear the Garmin once the study ended.

Figure 3

Week-Level Garmin Wear Adherence for Participants Who Provided at Least One Valid Day of Data over the Study Period (n = 32).



Note. Participant included in the two-time-point analysis.

Table 4. Caregiver report of intervention acceptability

Post-intervention survey item	CBPA (n = 25)	CBPA+Family (n=10)
Acceptability of overall intervention		
Caregiver satisfied with overall quality of program	3.3 (0.7)	3.3 (0.6)
Child enjoyed activity lessons	3.5 (0.5)	3.6 (0.5)
Acceptability of Garmin		
Child enjoyed using & wearing the Garmin	3.5 (0.7)	3.5 (0.7)
Using the Garmin was easy	3.3 (0.9)	3.0 (0.8)
Syncing Garmin was easy	3.2 (0.9)	2.7 (0.6)
Child is likely to use/wear the Garmin after this program ends	3.4 (0.8)	3.5 (0.7)
Child is satisfied with the Garmin	3.3 (0.7)	3.5 (0.5)
Acceptability of CBPA+Family intervention†		
I found the text messages to be helpful	-	3.2 (0.6)
I shared the information from the texts with my child	-	3.3 (0.7)
I liked how many text messages we got each week	-	3.1 (0.9)
I found the information in the newsletters to be helpful	-	3.2 (0.6)
I read each newsletter	-	2.8 (0.8)
I liked getting a newsletter each week	-	3.0 (0.6)
I liked how long the newsletters were	-	2.8 (0.8)

Note. Items were asked on a Likert scale: 1 = Strongly Disagree; 2 = Disagree; 3 = Agree; 4 = Strongly Agree; CBPA = classroom-based physical activity; SD = standard deviation; †only completed by CBPA+Family arm

Within the CBPA+Family arm, 88.9% of caregivers agreed or strongly agreed they found the text messages and newsletters to be helpful. When asked about what part of the newsletter caregivers liked best, preference was for the family physical activity suggestions (reported by 54.5%), weekly behavior change topic (reported by 27.3%) and child activity ideas throughout the day. 63.6% of caregivers reported engaging in the family physical activity ideas one day a week and 27.3% reported engaging in these activities 2-3 days a week. 81.2% of caregivers reported their child engaged in the suggested activities throughout the day on a regular basis, with 9.1% reporting engagement in suggested activities 4-5 days a week, 36.4% reporting engagement in the suggested activities 2-3 days a week, and an additional 36.4% reporting engagement on one day a week.

Summary of Open-Ended Questions

When asked what the child liked most about the Stay Active program, many caregivers mentioned their child was more motivated to be active and that the dyad was more likely to exercise together as a result of the intervention. These impacts appeared to be observed more in relation to the CBPA than the family-based supports. Two quotes that summarized the responses were "[child] enjoyed the social interaction aspect of the stay active program. It was not only great for her physical and mental health but also emotional health so that her and her friends could be collaborating toward a goal other than school grades," and "She loved getting the Garmin and doing the kickboxing." Caregivers also reported their child liked the Garmin device and/or an aspect of the device (e.g., seeing/tracking their steps) as well as the physical activity lessons.

When asked for suggestions to improve the Stay Active Program, some caregivers noted they would have liked the Garmin to be "better" and to receive more information on how to use the features of the Garmin. This was mentioned more in the CBPA arm, where the device was solely used by researchers to measure activity and families didn't receive feedback based on Garmin data. Some caregivers commented on having difficulty syncing the Garmin device, demonstrated by quotes like, "[child] would forget a lot to sync it up," and "[the program should] make syncing better." Caregivers in the CBPA arm also suggested to provide more structured activities outside of the CBPA (activity ideas were provided in the CBPA+Family arm). One caregiver stated, "if you could send videos for activity ideas for families and the child to do at homework that would be helpful."

When families in the CBPA+Family were asked to highlight what they liked and areas for improvements in the text messages and newsletters, most caregivers reported they did not dislike anything about the text messages and newsletters. Caregivers reported they enjoyed the family activity ideas within the newsletter, "The family activities were great for getting my family to work together and do activities together." It was also noted that the text messages were helpful reminders to be active and/or wear the Garmin device as well as for providing the caregiver with feedback on their child's activity level. Two notable quotes were, "it would help remind me to remind [child] to wear his watch;" and "they were a great reminder for my child and I, if she needed to get more steps to meet her goal."

Discussion

The present findings showed that the remote CBPA, which was included in both intervention arms, was feasible to deliver, acceptable, and effective for supporting increases in children's physical activity. This is an encouraging finding because remote delivery models have promise for improving uptake and implementation rates of CBPA by involving CBPA leaders outside of the classroom and reaching more students and classrooms at once. The findings around the added family-based mHealth intervention were more mixed. Participants in the combined CBPA+Family arm experienced large increases in physical activity, but since children's activity increased similarly in both arms, the family-based supports did not appear to result in added physical activity benefits over and above CBPA alone. However, findings generally supported the feasibility and acceptability of adding individualized mHealth intervention tools to school-based and other structured physical activity interventions to target multiple levels of influence and overall physical activity more holistically. The finding that participants in the CBPA+Family arm adhered to wearing the Garmin monitor later into the study suggests that mHealth tools, such as text messaging, may support more sustained adherence to physical activity measurements and potentially intervention engagement. Thus, using text messaging with consumer wearables to engage caregivers and children to interact in support of the child's physical activity appears to be a promising intervention 'layer' that may complement other intervention strategies (e.g., structured physical activity interventions, face-to-face interventions).

The finding that remote CBPA was effective for increasing children's activity aligns with previous research showing the effectiveness of in-person CBPA (Eisenmann et al., 2008; Watson et al., 2017). The current study expanded on previous research by testing a fully remote CBPA program (i.e., all teachers and students attended the 'classroom' online). During the intervention, MVPA increased substantially in both arms, by an average of ~45 minutes/day across the entire day and ~15 minutes/day during school hours. The latter result is towards the upper end of the typical changes of ~4-20 minutes/day observed in most previous CBPA interventions (Watson et al., 2017), suggesting that providing CBPA remotely is not likely to have diminished impacts as compared to in-person CBPA. The large increases in physical activity outside of school hours observed in the CBPA-only arm suggest that some of the benefits of the CBPA may have carried over into other settings, such as by fostering children's excitement and motivation for being active across the day. Thus, when implemented consistently, CBPA by itself may have a greater impact on children's overall physical activity than previously recognized based on other studies (Watson et al., 2017). It is also possible that the circumstances related to the COVID-19 pandemic impacted participants' changes in physical activity over the course of the intervention. Similar to other studies of youth's physical activity during the pandemic, children's baseline levels of MVPA in the present study were extremely low, <10 minutes/day on average (Dunton, Do, & Wang, 2020). Although participants were in fully remote learning during the entire study period (November – December 2020), it is possible they began to leave their home more and interact with others over the course of the study, providing more opportunities for physical activity that may not have been directly stimulated by the intervention. Future research should identify low-cost (i.e., cost effective) ways to deliver remote CBPA more widely and maximize implementation as it is not yet clear whether a lower-cost approach to remote CBPA (e.g., CBPA delivered by volunteers to multiple classrooms at a time) would result in compromises to implementation rates. Future studies should also test whether remotely delivered CBPA is effective during in-person learning (i.e., traditional classroom settings).

The CBPA+Family arm expanded on the CBPA component by increasing contact through added mHealth supports in an effort to target children and caregivers together, creating a more multilevel and multi-setting approach. Although these family-based supports did not lead to increased effectiveness, as shown by the lack of differences in changes in physical activity between the two study arms, the added support was accepted by families and appeared to be valuable in supporting adherence to wearing the Garmin monitor further into the intervention period (wear adherence at Week 8 was 44% in CBPA+Family vs. 29% in CBPA). It is possible that the lack of differences in physical activity between arms was due to the relatively low dose of the mHealth intervention. More intensive mHealth interventions for physical activity have included additional strategies such as providing monetary incentives, using two-way texting, modifying the texting frequency, or sending messages at opportune times (Head, Noar, Iannarino, & Harrington, 2013; Ludwig et al., 2018; Ortega & Cushing, 2020; Walton et al., 2018). Future studies should build on this trial by determining more broadly whether and what dose of family intervention strategies can extend physical activity benefits beyond what is provided by current non-mHealth strategies (e.g., environmental, in-person). Research should also test the additive impacts of providing family support through mHealth and in-person methodology, with consideration of intervention scalability and time commitments.

The finding that the mHealth tools may support children to wear the Garmin for a longer period of time appears promising, as motivating children to wear a monitor for sustained periods is challenging (Bohm, Karwiese, Böhm, Oberhoffer, 2019). Engagement with the intervention has been shown to be a critical factor in physical activity interventions, whether delivered in-person, in groups, or via mHealth as higher levels of engagement correspond to larger improvements in outcomes (Mclaughlin et al., 2021). In the CBPA+Family arm, the individualized text message content based on the child's Garmin step counts and goal achievements, along with the engagement of the caregiver and child together, may have been drivers of more sustained use of the Garmin. The use of automated text messaging systems, like the one developed for the Stay Active intervention, is particularly promising because large numbers of participants can be reached with relatively few human resources. This supports scalability of self-regulation tools with individualized tailoring using data from consumer wearables. As more efforts are needed to increase and understand engagement, future studies could compare various engagement strategies using adaptive designs and micro-randomized trials (Collins, Murphy, & Strecher, 2007; Walton, Nahum-Shani, Crosby, Klasnja, & Murphy, 2018).

Overall, there is promise for integrating mHealth tools with community-based interventions to provide additional, more holistic support for physical activity. While in the present study, the mHealth supports were focused on Garmin wearables, text messages, and online newsletters to support physical activity, other studies have used web-based tools and mobile applications more broadly (Jake-Schoffman et al., 2018; McCloskey et al., 2018; Ullmann et al., 2018). Such interventions have targeted multiple levels of influence and provided resources, ideas, and/or structured activity across each targeted level. A novel aspect of the CBPA+Family arm in the present study was the targeting of both schools (i.e., teachers and classrooms) and families (i.e., caregiver/child dyads). Responses to the open-ended questions indicated the intervention may have elicited positive interactions at multiple levels, showing the importance of social relationships in supporting activity. These interactions occurred between children and their peers, children and the activity leaders, and children and their caregivers. Further, caregivers in the CBPA+Family arm enjoyed the family activity ideas and reported being more motivated to be active as a family. These findings support previous work showing parents want to be included and engaged in physical activity interventions targeting their child(ren) (Noonan, Boddy, Fairclough, & Knowles, 2017). Future research should consider additional strategies for promoting social interactions to support physical activity.

Strengths and Limitations

The main strengths of this study were the use of evidence-based CBPA and mHealth tools for supporting physical activity, and the use of behavior change theories to guide the mHealth content (i.e., text messages and newsletters) (Fedele et al., 2017; Michie et al., 2009). Another strength was the continuous monitoring of physical activity, which provided high resolution data on both adherence (a marker of engagement) and physical activity metrics. Although a study limitation was the prevalence of missing Garmin data, the similarity in results across the various statistical approaches that accounted for missing data improves confidence in the study findings. Another limitation is that, while the intent was for the Garmin to be used solely as an objective measure of physical activity in the CBPA arm, the visual display and tracking of steps may have led to increased activity (Bronikowski, Bronikowska Glapa, 2016), potentially causing the two arms to be more similar. Even though randomization occurred after baseline data collection, enrollment rates were not equivalent between the arms and there were imbalances in participant characteristics due to the small sample. For example, participants in the CBPA arm were more likely to earn at least $30,000/year and much more likely to have a college degree. Since the clustering of participants within classrooms/schools was not able to be accounted for within the statistical analyses, the standard errors may have been slightly underestimated. Since the participant surveys exhibited low response rates, the acceptability data may not generalize to all participants enrolled. The pandemic created several challenges to data collection, such as the inability to meet with families in person, and possibly heightened barriers for low-income families that made it difficult for them to complete research tasks (e.g., surveys).

Conclusion

Remote delivery of CBPA led by an activity instructor over a video meeting platform was feasible and effective for supporting increases in children's physical activity. This scalable delivery model may support increased uptake and rates of implementation of CBPA. Additionally, mHealth tools, such as text messages integrated with data from consumer wearables, have promise for enhancing school- and community-based physical activity interventions. While our study did not support the effectiveness of mHealth tools for providing additional benefits to activity over and above a CBPA only intervention, they were found to be acceptable and appeared to support intervention engagement through more sustained use of the Garmin. These mHealth tools can expand on and complement established intervention strategies such as in-person supports and structured physical activity, creating more multilevel and multi-setting intervention packages, though more research is needed to better understand additive impacts of such multiapproach packages.

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Conflicts of interest

All authors report no conflicts of interest.

Author Contribution

Conceptualization, J.A.C., B.F., H.C., A.M.D., A.O., M.S., M.M.; Methodology, J.A.C., A.K, A.O., C.S. M.M., B.M.; Investigation, M.M., C.S., M.M., B.M., M.S.; Data analysis, J.A.C., B.F., P.R.H., M.S., V.S., M.M.; Writing original draft – B.F., P.R.H., J.A.C.; Writing – Review & editing A.O., P.R.H., M.M, C.S., M.S., B.M., M.M, A.K., H.C., A.M.D., V.S., J.A.C.; Funding Acquisition, J.A.C.; Resources, J.A.C.; Supervision, J.A.C.

References

Böhm B, Karwiese SD, Böhm H, Oberhoffer R. (2019). Effects of Mobile Health Including Wearable Activity Trackers to Increase Physical Activity Outcomes Among Healthy Children and Adolescents: Systematic Review. JMIR Mhealth Uhealth. 7(4):e8298 doi: 10.2196/mhealth.8298

Brazendale, K., Beets, M. W., Weaver, R. G., Pate, R. R., Turner-McGrievy, G. M., Kaczynski, A. T., ... & von Hippel, P. T. (2017). Understanding differences between summer vs. school obesogenic behaviors of children: the structured days hypothesis. International Journal of Behavioral Nutrition and Physical Activity, 14(1), 1-14.

Bronikowski M, Bronikowska M, Glapa A. (2016). Do they need goals or support? A report from a goal-setting intervention using physical activity monitors in youth. Int J Environ Res Public Health. 13(13),9.

Carlson, J. A., Sallis, J.F., Norman, G.J., McKenzie, T.L., Kerr, J., Arredondo, E.M., Madanat, H., Mignano, A.M., Cain, K.L., Elder, J.P., & Saelens, B.E. (2013). Elementary school practices and children's objectively measured physical activity during school. Preventive Medicine, 57(5), 591-595. PMC3904859

Carlson, J. A., Engelberg, J. K., Cain, K. L., Conway, T. L., Mignano, A. M., Bonilla, E. A., & Sallis, J. F. (2015). Implementing classroom physical activity breaks: Associations with student physical activity and classroom behavior. Preventive medicine, 81, 67-72.

Carlson, J. A., Schipperijn, J., Kerr, J., Saelens, B. E., Natarajan, L., Frank, L. D., ... & Sallis, J. F. (2016). Locations of physical activity as assessed by GPS in young adolescents. Pediatrics, 137(1).

Chi, D. L., Luu, M., & Chu, F. (2017). A scoping review of epidemiologic risk factors for pediatric obesity: implications for future childhood obesity and dental caries prevention research. Journal of Public Health Dentistry, 77, S8-S31.

Christodoulos AD, Douda HT, Polykratis M, et al. Attitudes towards exercise and physical activity behaviours in Greek schoolchildren after a yearlong health education intervention. Br J Sports Med 2006;40:367–71.

Classroom Physical Activity Ideas and Tips. (2021, March 30). Retrieved August 5, 2020, from https://schoolspringboard.org/resources/classroom-physical-activity-ideas-and-tips/

Collins, L. M., Murphy, S. A., & Strecher, V. (2007). The multiphase optimization strategy (MOST) and the sequential multiple assignment randomized trial (SMART): new methods for more potent eHealth interventions. American journal of preventive medicine, 32(5), S112-S118.

Cushing, C. C., Bejarano, C. M., Ortega, A., Sayre, N., Fedele, D. A., & Smyth, J. M. (2021). Adaptive mHealth Intervention for Adolescent Physical Activity Promotion. Journal of Pediatric Psychology.

Dale, L. P., Vanderloo, L., Moore, S., & Faulkner, G. (2019). Physical activity and depression, anxiety, and self-esteem in children and youth: an umbrella systematic review. Mental Health and Physical Activity, 16, 66-79.

Direito, A., Carraça, E., Rawstorn, J., Whittaker, R., & Maddison, R. (2017). mHealth Technologies to Influence Physical Activity and Sedentary Behaviors: Behavior Change Techniques, Systematic Review and Meta-Analysis of Randomized Controlled Trials. Annals of behavioral medicine: a publication of the Society of Behavioral Medicine, 51(2), 226–239. https://doi.org/10.1007/s12160-016-9846-0

Dunton, G.F., Do, B. & Wang, S.D. (2020). Early effects of the COVID-19 pandemic on physical activity and sedentary behavior in children living in the U.S. BMC Public Health 20, 1351. https://doi.org/10.1186/s12889-020-09429-3

Eisenmann, J. C., Gentile, D. A., Welk, G. J., Callahan, R., Strickland, S., Walsh, M., & Walsh, D. A. (2008). SWITCH: rationale, design, and implementation of a community, school, and family-based intervention to modify behaviors related to childhood obesity. BMC Public health, 8(1), 1-10.

Elementary and Secondary Information System, National Center for Education Statistics, nces.ed.gov/ccd/elsi/default.aspx?agree=0. Accessed on May 2, 2021.

Erwin, H. E., Beighle, A., Morgan, C. F., & Noland, M. (2011). Effect of a low-cost, teacher-directed classroom intervention on elementary students' physical activity. The Journal of School Health, 81(8), 455–461.

Fedele, D. A., Cushing, C. C., Fritz, A., Amaro, C. M., & Ortega, A. (2017). Mobile health interventions for improving health outcomes in youth: a meta-analysis. *JAMA pediatrics*, *171*(5), 461-469.

Friel, C. P., Duran, A. T., Shechter, A., & Diaz, K. M. (2020). US Children Meeting Physical Activity, Screen Time, and Sleep Guidelines. American Journal of Preventive Medicine, 59(4), 513-521.

Garmin Ltd. (2018). vívosmart 4 - Step Goal. Retrieved June 2, 2021, from https://www8.garmin.com/manuals/webhelp/vivosmart4/EN-US/GUID-5AC1A1BC-EFB3-40EC-9C18-2BF1D6218E69.html

GoNoodle (2015, July 24). Rock Out - Fresh Start Fitness [Video]. YouTube. https://www.youtube.com/watch?v=3KReaoKLA-4&list=PLAwOTEJXH-cN4YyNnBR19QBdcM7Kn79Qs&index=1.

Head, K. J., Noar, S. M., Iannarino, N. T., & Harrington, N. G. (2013). Efficacy of text messaging-based interventions for health promotion: a meta-analysis. Social science & medicine, 97, 41-48.

Jake-Schoffman, D. E., Turner-McGrievy, G., Wilcox, S., Moore, J. B., Hussey, J. R., & Kaczynski, A. T. (2018). The MFIT (Motivating Families with Interactive Technology) Study: a randomized pilot to promote physical activity and healthy eating through mobile technology. Journal of Technology in Behavioral Science, 3(3), 179-189.

Janssen I, Leblanc AG. 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 2010;7:40

Klinker, C.D., Schipperijn, J., Christian, H., Kerr, J., Ersbøll, A.K., Troelsen, J. (2014). Using accelerometers and global positioning system devices to assess gender and age differences in children's school, transport, leisure and home based physical activity. International Journal of Behavioral Nutrition and Physical Activity, 11(1):8. https://doi.org/10.1186/1479-5868-11-8.

Luepker RV, Perry CL, McKinlay SM, et al. Outcomes of a field trial to improve children's dietary patterns and physical activity. The Child and Adolescent Trial for Cardiovascular Health (CATCH). JAMA 1996;275:768–76.

McCloskey, M. L., Thompson, D. A., Chamberlin, B., Clark, L., Johnson, S. L., & Bellows, L. L. (2018). Mobile device use among rural, low-income families and the feasibility of an app to encourage preschoolers' physical activity: qualitative study. JMIR pediatrics and parenting, 1(2), e10858.

Mclaughlin, M., Delaney, T., Hall, A., Byaruhanga, J., Mackie, P., Grady, A., Reilly, K., Campbell, E., Sutherland, R., Wiggers, J., & Wolfenden, L. (2021). Associations Between Digital Health Intervention Engagement, Physical Activity, and Sedentary Behavior: Systematic Review and Meta-analysis. Journal of medical Internet research, 23(2), e23180. https://doi.org/10.2196/23180

Messing, S., Rütten, A., Abu-Omar, K., Ungerer-Röhrich, U., Goodwin, L., Burlacu, I., & Gediga, G. (2019). How can physical activity be promoted among children and adolescents? A systematic review of reviews across settings. Frontiers in public health, 7, 55.

Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). BMJ. 2012;345:e5888

Noonan, R. J., Boddy, L. M., Fairclough, S. J., & Knowles, Z. R. (2017). Parental perceptions on children's out-of-school physical activity and family-based physical activity. Early Child Development and Care, 187(12), 1909-1924.

Norton DE, Froelicher ES, Waters CM, Carrieri-Kohlman V. Parental influence on models of primary prevention of cardiovascular disease in children. European Journal Cardiovascular Nursing 2003;2:311–22.

Ortega, A., Cushing, C.C. (2020). Developing Empirical Decision Points to Improve the Timing of Adaptive Digital Health Physical Activity Interventions in Youth: Survival Analysis JMIR Mhealth Uhealth, 8(6):e17450

Ortega, A., Bejarano, C. M., Cushing, C. C., Staggs, V. S., Papa, A. E., Steel, C., & Carlson, J. A. (2020). Differences in adolescent activity and dietary behaviors across home, school, and other locations warrant location-specific intervention approaches. International Journal of Behavioral Nutrition and Physical Activity, 17(1), 1-12.

Poitras VJ, Gray CE, Borghese MM, Carson V, Chaput J-P, Janssen I, Katzmarzyk PT, Pate RR, Connor Gorber S, Kho ME, Sampson M, Tremblay MS. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. Applied Physiology Nutrition, and Metabolism. 2016;41(6 (Suppl. 3):S197–239. https://doi.org/10.1139/apnm-2015-0663

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rhodes, R. E., Guerrero, M. D., Vanderloo, L. M., Barbeau, K., Birken, C. S., Chaput, J. P., ... & Tremblay, M. S. (2020). Development of a consensus statement on the role of the family in the physical activity, sedentary, and sleep behaviours of children and youth. International Journal of Behavioral Nutrition and Physical Activity, 17(1), 1-31.

Rizopoulos, D. (2010). JM: An R package for the joint modelling of longitudinal and time-to-event data. Journal of Statistical Software (Online), 35(9), 1-33.

Sallis J, Prochaska J, Taylor W. A review of correlates of physical activity of children and adolescents. (2000). Medicine & Science in Sports & Exercise 5 :963–75.

Salmon, J., Booth, M. L., Phongsavan, P., Murphy, N., & Timperio, A. (2007). Promoting physical activity participation among children and adolescents. Epidemiologic reviews, 29(1), 144-159.

Sanford Health (2021). fitFlow. Website. https://fit.sanfordhealth.org/resources/fitflow-activity.

Shapiro J.R., Bauer S., Hamer R.M., Kordy H., Ward D. & Bulik C.M. (2008). Use of text messaging for monitoring sugar-sweetened beverages, physical activity, and screen time in children: A pilot study. Journal of Nutrition Education & Behavior, 40(6), 385–391.

Spinelli M, Lionetti F, Setti A, Fasolo M. Parenting Stress During the COVID-19 Outbreak: Socioeconomic and Environmental Risk Factors and Implications for Children Emotion Regulation. Fam Process. 2020 Sep 28. doi: 10.1111/famp.12601. EPUB ahead of print. PMID: 32985703.

Stevens, J., Story, M., Ring, K., Murray, D. M., Cornell, C. E., & Gittelsohn, J. (2003). The impact of the Pathways intervention on psychosocial variables related to diet and physical activity in American Indian schoolchildren. Preventive medicine, 37, S70-S79.

Tassitano, R. M., Weaver, R. G., Tenório, M. C. M., Brazendale, K., & Beets, M. W. (2020). Physical activity and sedentary time of youth in structured settings: a systematic review and meta-analysis. International Journal of Behavioral Nutrition and Physical Activity, 17(1), 1-17.

Ullmann, G., Kedia, S. K., Homayouni, R., Akkus, C., Schmidt, M., Klesges, L. M., & Ward, K. D. (2018). Memphis FitKids: implementing a mobile-friendly web-based application to enhance parents' participation in improving child health. BMC public health, 18(1), 1-12.

Van Sluijs, E. M., McMinn, A. M., & Griffin, S. J. (2007). Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. Bmj, 335(7622), 703.

Warren JM, Henry CJK, Lightowler HJ, et al. (2003). Evaluation of a pilot school programme aimed at the prevention of obesity in children. Health Promotion International. 18:287–96.

Walton, A., Nahum-Shani, I., Crosby, L., Klasnja, P., & Murphy, S. (2018). Optimizing digital integrated care via micro-randomized trials. Clinical Pharmacology & Therapeutics, 104(1), 53-58.

Watson, A., Timperio, A., Brown, H., Best, K., & Hesketh, K. D. (2017). Effect of classroom-based physical activity interventions on academic and physical activity outcomes: a systematic review and meta-analysis. International Journal of Behavioral Nutrition and Physical Activity, 14(1), 1-24.