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Parental engagement and implementation fidelity in a mHealth motor skills intervention for young children

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ABSTRACT

Introduction: Mobile apps (i.e. mHealth) provide unprecedented opportunity for widespread dissemination of health behavior programs. However, for programs directed towards young children, parental engagement may explain differing results of mHealth programs. Within the context of an app-based fundamental motor skill (FMS) intervention that improved children's motor skills (PLAY), this paper examines parents' fidelity to the intervention and the extent to which fidelity was related to children's motor skill improvements.

Methods: In the PLAY trial, 72 children aged 3–5 years were randomized for their parents to access a Motor Skills app or Free Play app for a 12-week intervention. The Motor Skills app contained lessons, videos, and activity breaks totaling 1 h/week of directed FMS instruction by the parent to the child over a 12-week period. The Free Play app was similar in appearance and format but focused on unstructured physical activity. Children's FMS were evaluated with the Test of Gross Motor Development (TGMD-3) at baseline, 12-weeks, and 24-week follow-up. Implementation fidelity data included dosage completed (activity breaks completed), parental engagement (duration of video views), and quality of intervention delivery (feasibility and acceptability). Dosage and engagement were dichotomized within the Motor Skills condition into high vs. low. Linear mixed effects models were used to examine the association of dosage completed and parental engagement with changes in children's FMS both within and between conditions. The level of significance was set at 0.05 for all analyses.

Results: Children completed 70% (8.4 of 12 h) of the prescribed activity breaks based on parental report in the Motor Skills condition and 87% (10.4 of 12 h) in the Free Play condition (not significantly different). Parental engagement based on video viewing duration for the Motor Skills condition was on average 8.0 ± 8.6 of the 9.8 available minutes and for the Free Play condition was 5.0 ± 5.5 of the available 18 min, with no significant difference between conditions. Parents rated high acceptability and usability for both apps. Children in the Motor Skills condition improved their FMS more than children in the Free Play condition regardless of whether they were classified as receiving high or low dosage or high or low parental engagement.

Conclusion: Parents and children consistently engaged with a 12-week Motor Skills app intervention, and the salience of FMS improvements did not differ by the level of parent fidelity or engagement with the mHealth app. The intervention potency, parental engagement, and

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dosage completed were sufficient to produce the desired child motor skills improvements.

Introduction

The preschool years are a critical time for children to acquire and refine basic motor skills such as running, jumping, and kicking a ball (Clark and Metcalfe 2002). These fundamental motor skills (FMS) provide a foundation for more complex movements, and mastery over these skills builds children's competence and confidence to take part in lifelong physical activity (PA) (Cameron et al. 2020; Lubans et al. 2010). Yet standardized assessments of young children indicate 77% ranked below the 25th percentile on motor skills, indicating many children have low or very low motor skill levels in the preschool years (Brian et al. 2019). A purported reason for this motor skill deficit is limited opportunities to engage in activities to practice motor skills, as these skills do not develop innately. Children should be taught, reinforced, and have ample opportunities for guided practice of FMS within structured physically active play (Logan et al. 2012). Impairment of learning FMS during the preschool years may lead to lower levels of PA into young adulthood (Barnett et al. 2009). Therefore, developing intervention strategies to improve FMS in early childhood is a public health priority (Campbell et al. 2015).

There is mounting evidence that FMS activities and instruction led by classroom teachers, community and sports coaches, physical educators, and motor development experts improve FMS in preschoolers (Fu et al. 2018; Johnstone et al. 2018; Lee et al. 2020; Robinson et al. 2018). However, these programs are limited in reach and accessibility due to the teacher turn over, resources, time, and costs involved. Interventions delivered over digital platforms such as electronic and mobile devices (i.e. e-&mHealth) can increase the reach and accessibility of FMS interventions to overcome these challenges. As a result, the development of e- and mHealth technologies such as mobile apps to promote FMS among preschoolers is an emerging area of research (Staiano et al. 2022; Swindle et al. 2022).

The PLAY app was developed in response to this need for more accessible FMS interventions for preschool-aged children in home-based settings (Staiano et al. 2022; Webster et al. 2020). PLAY is a 12-week curriculum delivered over an app for the parent, who in turn delivers the intervention to their child. In a randomized controlled trial of 72 children ages 3–5 y, parents were assigned to the PLAY motor skills app (Motor Skills) or to a version of the app that promoted unstructured physical activity (Free Play) as a control. Results indicated that over the 12-week program, children in the Motor Skills condition significantly improved their overall FMS including locomotor and ball skills compared to children in the Free Play condition, and these effects were sustained to 24-weeks (Staiano et al. 2022). To date, few studies have evaluated similar e- and mHealth technologies to increase health behaviors in preschool-age children and to our knowledge, none have evaluated the intervention fidelity of these programs like traditional, in-person interventions have previously. A recent systematic review (Swindle et al. 2022) reported that in apps that targeted physical activity, there was a lack of detail related to the implementation of digital interventions outside of feasibility.

Building on these promising results, the purpose of this secondary analysis is to examine implementation fidelity and engagement of the parents involved in PLAY and the extent to which dosage completed and parental engagement were related to children's FMS improvements within the Motor Skills condition. Implementation fidelity refers to the degree to which the implementation strategy supporting uptake and use of an innovation was implemented as intended (Carroll et al. 2007). Completed dose and quality of delivery are metrics of implementation fidelity that move beyond adherence and effects of the intervention (Breitenstein et al. 2010; Campbell et al. 2015; Stein, Sargent, and Rafaels 2007). Examining implementation fidelity within digital interventions will identify the feasibility of the intervention and the required training, time, and resources for parents to successfully implement the intervention and achieve changes in their child as seen in free-living controlled research studies (Breitenstein et al. 2010; Hermes et al. 2019; Johnstone et al. 2018).

Methods

In a randomized controlled trial, 72 children were assigned to either the Motor Skills app or the Free Play app. The study protocol was approved by the Institutional Review Board of Pennington Biomedical Research Center (PBRC), and parental written consent was obtained.

Sample size, participants and recruitment

A minimum sample size of 56 (28 in each group) was required to detect an effect size of 0.33 with 80% power for change in FMS scores between baseline and 12-week assessment (level of significance, $p = 0.05$). Enrolling 72 children allowed for 20% attrition across the 12-week program. Families were recruited for this study via convenience sampling in a Southeastern state of the U.S. between May 2019 and August 2019. Recruitment procedures involved distribution of flyers via childcare centers, email listserv, community events, and social media. Children were eligible if they were between 3 and 5 years of age, had no physical limitation to perform exercise, and had no mobility limitations reported by their parents to perform FMS activities. To avoid ceiling effects, children who had gross motor quotient at 'gifted or very advanced' (index score > 129) based on the Test of Gross Motor Development (TGMD-3) (Ulrich 2019) at baseline assessment were excluded. The child must have a parent who was willing to download and use the app on their smartphone or other mobile device, have no self-reported mobility limitation that impaired them to model FMS, and have no plan to move from the area during the study period (24-weeks).

The mean ± SD age of the children was 4.0 ± 0.8 years, and body mass index (BMI) percentile was 61.1 ± 28.4 at baseline. Approximately 57% (41 out of 72) of the children were girls. Based on parent report, 63% ($n = 45$) of the children were White and 26% ($n = 19$) were African American. Most (58 out of 72) of the parents had an Associate's or Bachelor's degree or higher education level. There were no statistically significant baseline differences in the primary variables of interest between the two conditions or between those who did vs. did not complete the assessment visits.

Randomization and blinding

Children were assigned in a 1:1 ratio to condition (Motor Skills or Free Play) using a stratified block randomization scheme accounting for child's biological sex and baseline FMS score. Investigators and data assessors were blinded to intervention assignment. Families knew their intervention group; however, they were not informed about the specific intervention outcomes.

Study procedures

The detailed study procedures were published elsewhere (Webster et al. 2020). In brief, the parent completed a web screener followed by a screening visit with their child at PBRC's Translational Research Clinic for Children or a local recreational facility. The screening visit included confirming eligibility, completing a standardized assessment of FMS on the child, and administering surveys to parents. At the baseline visit, the parent and child completed questionnaires, and child height and weight were measured. After completion of data collection, an unblinded staff member randomized the child using a computerized module and helped the parent download the PLAY app to their smartphone. The parents were provided with a unique code that enabled them to access and use the randomly assigned version of the app (either the Motor Skills version or the Free Play version depending on treatment assignment). Each parent was briefly trained on how to use the app, access the lessons, view the videos, and follow instructions to perform the activity break. The research staff member did a brief demonstration of the first lesson and activity break to model for the parents how to use the app and engage the child in an activity break.

Parents and children completed a post-intervention assessment at week 12 and a follow-up assessment at week 24. The PLAY app was deleted from the parent's smartphone at the follow-up visit (24-weeks). Each child was compensated $75 for their participation in this study ($25 for each visit).

Intervention

The PLAY app was developed by research scientists with the CyberFision app development company (Baton Rouge, LA). PLAY is web-based, available on the App Store (for iPhone) and Google Play (for Android), and has two versions (one focused on Motor Skills and the other on Free Play).

The PLAY app delivers a new lesson each week that features a targeted motor skill and provides prescribed activities ('activity breaks') and brief videos of young children demonstrating the skills and activities. Each week's lesson is accompanied by a 12-minute activity break for the child that includes five activities to reinforce the specific skill, e.g. jump like a frog. Household items like balls or socks can be used for the activities such that no specialized equipment is required. The parent and child complete the same activity break five times over the course of the week, for a total of 1 h of prescribed activity each week. Text was also provided for parents to read prescribed activity break tasks. The dosage of 1 h of prescribed activity per week for a total of 12 h over the course of the 12-week intervention was selected to align with similar dosages in prior in-person FMS interventions for children (Robinson, Palmer, and Bub 2016). The written description of each week's activity break is accompanied by a brief video (range 24–39 s) with preschool-aged children modeling the activity. A young boy and girl narrated the content by naming the activity. The children in the videos are from diverse racial/ethnic backgrounds.

In addition to the brief video, the targeted motor skill for each week is described with a series of five video clips 3- to 6-seconds in length that break down the components of the targeted motor skill so that the parent can identify which skill components the child has mastered and which skill components the child needs to learn and practice. The parent is asked to integrate the new skills into the activity breaks, e.g. for jumping, working with the child to take off and land with feet together. Overall, there are 72 videos (12 weekly videos plus 5 skill videos each week) for a total of 9.8 min of video content overall. Finally, the parent and child are asked to press a star on the app to indicate each day they complete a 12-minute activity break, up to 5 stars each week for a total of 60 stars over the course of the 12-weeks. Parents are encouraged to reward children (e.g. non-food items) for performing activity breaks.

The Free Play app looks similar visually but rather than focusing on targeted motor skills, each week's lesson provides strategies the parent can use to create an environment conducive to the child's active play. For example, weekly themes include ideas for outdoor play, creating activity zones with low-cost items, and using household chores to promote the child's movement. The curriculum was adapted from a previous study that increased children's PA but did not have explicit focus on FMS (Newton et al. 2014). The Free Play app also contains weekly videos (range 56–107 s, total 18 min over 12 weeks); these videos contain photos, brief text, and an adult narrator. Text was also provided for parents to read prescribed activity break tasks. Identical to the Motor Skills app, the Free Play app includes a star for the parent and child to select for each 12-minute free play activity break completed during the week, with a goal of 5 per week for a total of 60 stars over the course of the 12-weeks.

During the trial, research staff monitored the usage data and contacted parents via text or phone call when they did not use the app during a 2-week period to confirm whether they experienced any technical difficulties in the app.

Dosage completed

Dosage completed of the intervention was quantified by the number of stars selected in the app by the parent and child over the course of the intervention, with each star representing one completed 12-minute activity break per day.

Parental engagement

Parental engagement was measured by internal app usage data including number of videos accessed and total minutes viewing the videos. Parents could view videos repeatedly, thus some users exceeded the available minutes (9.8 min in the Motor Skills app and 18 min in the Free Play app).

Quality and characteristics of intervention delivery

Parents completed weekly surveys within the app to report qualitatively where the child completed the activity breaks, whether the parent read the weekly lesson, and supplies used during the activity breaks.

Acceptability

As previously described (Staiano et al. 2022), app acceptability was measured by administering Likert-based scale questions within the app to parents at week 4, 8, and 12 on overall satisfaction, helpfulness, ease of use, and likely to recommend to a friend. The rating scale was established following an order in which '1' indicated 'very unsatisfied/ unhelpful/ hard/ unlikely' and the highest order '5' indicated 'very satisfied/ helpful/ easy/ likely'.

FMS

The Test of Gross Motor Development (TGMD-3) is a valid and reliable direct observational assessment method of children's FMS (Ulrich 2019) and evaluates locomotor (gallop, skip, run, jump, hop, and slide) and ball skills (one-hand or two-hand strike, overhand or underhand throw, catch, kick, and dribble). Blinded administrators were trained prior to the study and established 99% reliability with the TGMD-3 author.

Data analysis

Descriptive data are presented as mean and standard deviation (for continuous variables such as average of video watching time) or as frequency and percentage (for nominal variables such as number of lessons or videos accessed by parents). The Motor Skills condition ($n = 35$) was analyzed overall and dichotomized into two balanced groups based on dosage completed (higher: reported completing ≥50 of 60 possible activity breaks, $n = 17$; lower: reported completing <50 of 60 possible activity breaks, $n = 18$) and engagement (higher: watched videos for ≥5 of 9.8 available minutes, $n = 17$; lower: watched videos for <5 of 9.8 available minutes, $n = 18$). The dichotomization was somewhat arbitrary based on limited precedent for what constitutes high app engagement in a motor skills intervention for young children. Linear mixed effects models were used to estimate the influence of dosage and engagement on changes in children's TGMD-3 scores. Linear models were also used to assess differences of the change scores between the two conditions. The level of significance was set at 0.05 for all analyses.

Results

As previously reported (Staiano et al. 2022), 72 children completed baseline assessment (35 in Motor Skills and 37 in Free Play), 68 completed assessments at week 12, and 69 completed the final week 24 follow-up visit.

Dosage completed

Based on the number of stars selected by families, children completed 70% of the prescribed dosage in the Motor Skills condition (completed on average 8.4 of possible 12 h of prescribed activity bouts). On a weekly basis, this equals 3.5 ± 0.6 activity bouts (of possible 5). When dichotomized in half by dosage completed, within the higher dosage completed group, children completed 57.1 ± 3.4 activity breaks (11.4 h or 95% of the prescribed 12 h). Within the lower dosage completed group, children completed 28.2 ± 15.3 activity breaks (5.6 h or 47% of the prescribed 12 h).

Children completed 87% of the prescribed dosage in the Free Play condition (10.4 of possible 12 h). On a weekly basis, children completed 4.3 ± 0.3 of 5 possible activity breaks in the Free Play condition.

There was no statistically significant difference in dosage completed between conditions. There were no significant sociodemographic differences in dosage completed between conditions (Motor Skills vs. Free Play) or within the groups (high vs low dosage completed in the Motor Skills condition) in terms of children's age, sex, race/ethnicity, or parents' education level (all P values > 0.05). There were no significant differences in baseline TGMD-3 scores between high vs. low dosage completed. In the Motor Skills condition, the number of completed activity bouts was relatively stable for the first 2 weeks, declined during weeks 3–4, remained stable through week 11, and declined in week 12. In the Free Play condition, the number of activity breaks completed remained relatively stable throughout the intervention with a decline in week 12. See Figure 1.

Parental engagement

Parental engagement based on video viewing duration for the Motor Skills condition was 8.0 ± 8.6 of the 9.8 available minutes. Parents could watch videos repeatedly, so some exceeded the 9.8 available minutes. Among the higher engagement group in the Motor Skills condition, parents viewed

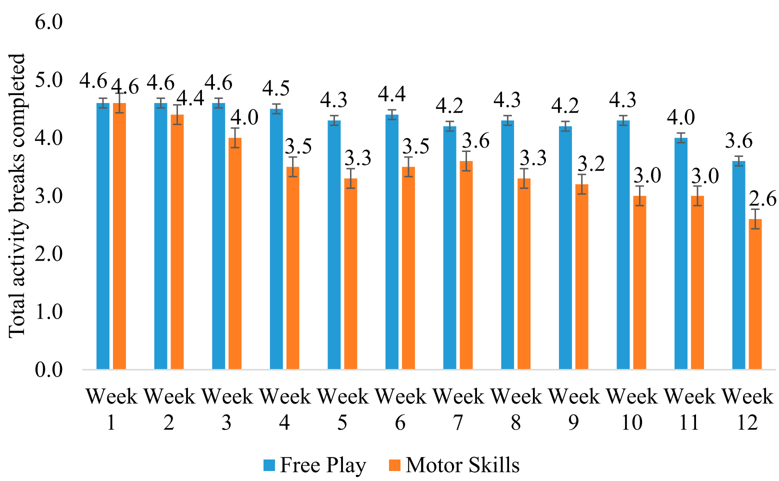

Figure 1. Average weekly star rating by condition.

on average 14.5 ± 8.4 min, and among the lower engagement group parents viewed 1.9 ± 1.5 min. Based on number of video views, the Motor Skills condition viewed 19.9 ± 16.7 of 72 total videos.

Parental engagement based on video view duration for the Free Play condition was 5.0 ± 5.5 min of the available 18 min, and number of video views averaged 3.0 ± 2.6 of 12 total videos.

There were no significant sociodemographic differences in parental engagement between conditions (Motor Skills vs. Free Play) or within the groups (high vs low engagement in the Motor Skills condition) in terms of children's age, sex, race/ethnicity, or parents' education level (all P values > 0.05). There were no significant differences in baseline TGMD-3 scores between high vs. low engagement with the exception of the video views, in which the higher video view group had a lower baseline TGMD-3 score than the lower video view group.

Most of the participants watched at least 1 video during week 1 (see Figure 2), including 26 of the 37 Free Play families and 30 of the 35 Motor Skills families. More families in the Motor Skills condition watched at least 1 video each week compared to the Free Play condition, though video views waned in both conditions over the course of the intervention.

Changes in child's FMS in relation to dosage completed

Both groups (higher and lower dosage completed) within the Motor Skills condition significantly improved TGMD-3 total percentile scores, locomotor percentile scores, and the gross motor index (all P values < 0.05) at week 12 and week 24 compared with week 0 (Table 1). Also, both groups in the Motor Skills condition improved every FMS metric (total percentile score, locomotor percentile score, ball skills percentile score, and gross motor index) at week 12 and week 24 more than the children in the Free Play condition (all P values < 0.05). Within the Motor Skills condition, there were no statistically significant differences at week 12 and week 24 in children's FMS improvements between the low vs. high dosage completed groups (all P values > 0.05).

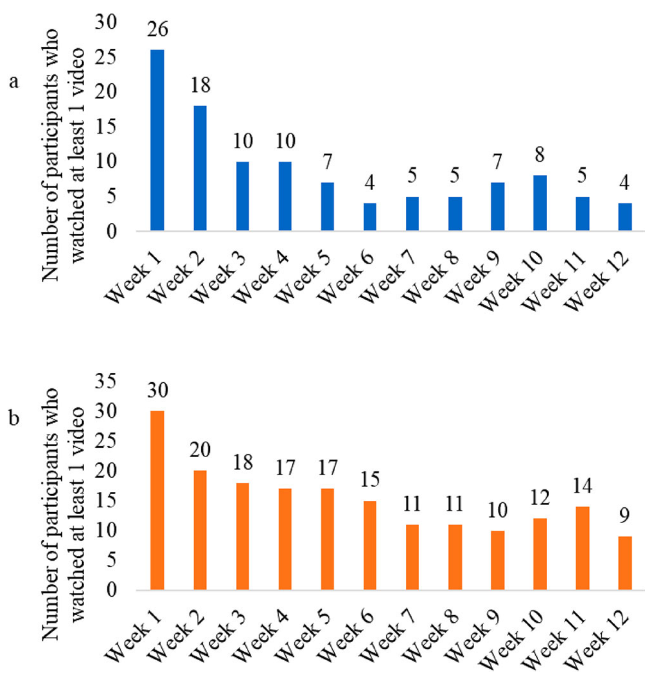

Figure 2. Number of users in the Free Play (Fig. a; $n = 37$) and Motor Skills (Fig. b; $n = 35$) conditions who watched at least one video by week.

Table 1. Changes in FMS within and between Motor Skills condition (including high and low dosage completed) and Free Play condition.

Outcome	Time point	Motor skills: Reported higher dosage Mean	SE	Motor skills: Reported lower dosage Mean	SE	Free play Mean	SE	Higher dosage (Motor skills) vs. Free play *P* value	Lower dosage (Motor skills) vs. Free play *P* value	Higher dosage (Motor skills) vs. Lower dosage (Motor skills) *P* value
Locomotor	W12-W0	13.8**	4.2	16.7**	4.4	−4.8	2.9	0.0005	0.0001	0.6284
Percentile	W24-W0	7.4*	2.9	15.5**	3.0	−4.7*	2.0	0.0011	<0.0001	0.0579
Ball Skills	W12-W0	4.7	4.5	12.1*	4.7	−7.2*	3.1	0.0326	0.001	0.2566
Percentile	W24-W0	4.0	4.2	4.0	4.4	−9.4*	2.9	0.0113	0.014	0.9994
Total	W12-W0	11.5**	3.2	15.9**	3.3	−5.3*	2.2	<0.0001	<0.0001	0.3377
Percentile	W24-W0	6.8*	2.4	11.9**	2.5	−6.1*	1.6	<0.0001	<0.0001	0.1366
Gross	W12-W0	5.3*	1.9	9.2**	2.0	−5.5*	1.3	<0.0001	<0.0001	0.1687
Motor Index	W24-W0	4.0*	1.6	6.9**	1.7	−5.6**	1.1	<0.0001	<0.0001	0.2076

W: Week; SE: Standard Error; * $P < 0.05$; ** $P < 0.0001$.

Changes in child's FMS in relation to parental app engagement

Children in both groups of parental engagement (watched videos for higher vs. lower duration) in the Motor Skills condition significantly improved TGMD-3 total percentile score, locomotor percentile score, and ball skills percentile score (all P values < 0.05) at week 12 and at week 24 compared to week 0 (Table 2). Further, the FMS improvements in the Motor Skills condition were higher than the Free Play condition among both the high and low parental engagement groups for every TGMD-3 metric. There was no statistically significant difference in FMS improvement among those families in the Motor Skills condition who watched the videos for higher vs. lower duration at week 12 (all P values > 0.05).

Quality and characteristics of intervention delivery

Of the 35 parents in the Motor Skills condition who completed the survey at week 1, the most common setting for the activity breaks was at home and indoors (reported by 69% of the parents). By contrast, the most common setting for the activity breaks in the Free Play condition was at home and outdoors (reported by 43% of parents).

Most of the parents in both conditions who completed surveys reported that they read/listened to the weekly lesson (week 3: 94% of 17 respondents in Motor Skills and 64% of 28 respondents in Free Play; week 7: 74% of 14 respondents in Motor Skills and 59% of 22 respondents in Free Play; week 11: 100% of 9 respondents in Motor Skills and 81% of 16 respondents in Free Play). However, several parents did not respond to the weekly surveys.

Related to supplies used for activity breaks, 50% of the parents (12 of 24 respondents) in Motor Skills and 32% (10 of 31 respondents) in Free Play at week 2 reported that their children used a ball during the activity breaks. Playing with baskets was the second most common supply used by the families in the Motor Skills condition (based on survey responses at weeks 2 and 6).

Acceptability

As previously reported (Staiano et al. 2022), participants in both conditions scored > 4 out of 5 possible points in terms of satisfaction, helpfulness, and ease of using the app across all three time points of assessments. Participants in the Motor Skills condition rated > 4 out of 5 possible points for likely to recommend the app to their friends. Table 3 presents mean values for each indicator at each time point.

Table 2. Changes in FMS within and between motor skills arm (including higher and shorter parental engagement based on video watching) and Free Play arm.

		Motor skills								
		Higher engagement		Lower engagement		Free play		Higher engagement (Motor skills) vs. Free play	Lower engagement (Motor skills) vs. Free play	Higher engagement (Motor skills) vs. lower engagement (Motor skills)
Outcome	Time point	Mean	SE	Mean	SE	Mean	SE	*P* value	*P* value	*P* value
Locomotor Percentile	W12-W0	15.2*	4.2	15.5*	4.4	−4.8	2.9	0.0002	0.0002	0.9605
	W24-W0	9.5*	3.0	12.8*	3.1	−4.7*	2.0	0.0002	<0.0001	0.4505
Ball Skills Percentile	W12-W0	11.2*	4.5	5.1	4.8	−7.2*	3.1	0.0014	0.0337	0.3568
	W24-W0	10.6*	4.2	−2.6	4.3	−9.4*	2.8	0.0002	0.1866	0.0317
Total Percentile	W12-W0	16.2**	3.2	11.0*	3.3	−5.3*	2.2	<0.0001	0.0001	0.2569
	W24-W0	11.8**	2.4	6.5*	2.4	−6.1*	1.6	<0.0001	<0.0001	0.1214
Gross Motor Index	W12-W0	7.6*	2.0	6.6*	2.1	−5.5*	1.4	<0.0001	<0.0001	0.7113
	W24-W0	6.1*	1.7	4.7*	1.7	−5.6**	1.1	<0.0001	<0.0001	0.5391

W: Week; SE: Standard Error; * $P < 0.05$; ** $P < 0.0001$.

Table 3. User scores for acceptability across the intervention by condition^.

	n	Satisfaction with application	Helpfulness of application	Application ease of use	Likely to recommend application to friend
Motor Skills					
Week 4	13	4.6 ± 0.5	4.6 ± 0.5	4.8 ± 0.3	4.1 ± 0.7
Week 8	12	4.5 ± 0.8	4.1 ± 1.0	4.8 ± 0.4	4.3 ± 0.6
Week 12	9	4.4 ± 0.7	4.3 ± 0.8	4.6 ± 0.5	4.2 ± 0.8
Free Play					
Week 4	23	4.2 ± 0.7	4.1 ± 0.9	4.8 ± 0.4	3.8 ± 1.3
Week 8	16	4.2 ± 1.2	4.5 ± 0.9	4.6 ± 0.8	4.0 ± 1.2
Week 12	12	4.3 ± 0.6	4.1 ± 1.0	4.7 ± 0.4	4.1 ± 0.9

^Assessed using a Likert scale (1-5), with higher numbers indicating more agreement with the statement.

Discussion

In a 12-week intervention delivered remotely via a mobile app to parents, preschool-aged children completed most of the prescribed dosage in both conditions. Parents engaged consistently with both the Motor Skills and Free Play app interventions and rated high scores on usability and acceptability. Engagement was related to the child's baseline FMS scores, such that parents of children with lower FMS scores viewed more videos. This is a promising findings, as it indicates parental self-selection to seek out training and support to help boost their child's performance. Children's FMS improvements in the Motor Skills condition were superior to changes in the Free Play condition regardless of whether the child was considered higher in dosage completed vs. lower or whether their parents engaged with the app more vs less time based on time spent viewing videos. These results indicate effectiveness of this 12-week app intervention to improve FMS even among children whose parents had lower implementation fidelity and lower app engagement.

There was variability in dosage completed in the Motor Skills intervention. Yet even among those children categorized in the lower group of dosage completed (the lower half of the sample), the children completed 6 h of the prescribed 12 h of activity bouts (vs. over 11 h in the higher half of dosage completed). Dichotomizing the sample in half is somewhat arbitrary, and follow-up moderation analyses were considered to examine if engagement and fidelity moderated effectiveness. Yet there was no significant interaction between dosage and engagement for each outcome of interest, and the relationship between dosage and engagement did not follow a linear correlation pattern. The salience of FMS improvements regardless of dosage completed points to the potential impact of this intervention with a parent working directly (one-on-one) with their child, improving children's FMS with only half of the prescribed parent-directed instruction. The study did not capture additional parent–child motor skills-based activities beyond the prescribed activity bouts, nor did the study monitor if the Motor Skills app intervention impacted parents' skills, knowledge, and attitudes towards physical activity, all of which may contribute to improving children's motor skills beyond the child's participation in the prescribed activity bouts.

e-&mHealth offers both advantages and limitations from in-person intervention delivery. In research trials designed to teach preschool teachers or non-motor skill experts how to deliver in-person FMS training, the teachers are typically evaluated on implementation fidelity metrics including assessing the teachers' own ability to learn, apply, demonstrate, scaffold, correct, and encourage/motivate the child within a prescribed FMS curriculum (Brian et al. 2019; Johnstone et al. 2018; Lee et al. 2020). The Motor Skills app in the PLAY study assigns the parent as the 'teacher' and provides a brief orientation and in-app videos and text to instruct the parent on how to deliver the intervention. The parent then delivers this intervention entirely remotely and not under the supervision of trained staff. As such, there are several implementation fidelity metrics that are not possible or practical to obtain. Even with in-person FMS interventions, there is a lack of reporting of implementation fidelity as noted in a recent systematic review and meta-analysis (Johnstone et al. 2018). Thus, it is difficult to determine the reliability and validity of the changes in outcome variables in relation to the intervention (Breitenstein et al. 2010; Hermes et al. 2019; Johnstone et al. 2018).

For these reasons, mHealth interventions have a 'black box' that makes it challenging to observe what the participant is doing in response to the app intervention. While the app provides usage data, these data are typically limited to how often the user opens/closes the apps, how much time they spend on the app, what links they click, and how much time they spend watching videos while maintaining ecological validity for the modality of this intervention. Therefore, it is challenging to obtain objective data on what behavior is being elicited from using the app, in this case if the child is completing the prescribed activity bouts correctly, if the parent is providing accurate instruction, and if the child is making improvements on their motor skills. Whereas supervised, structured, in-person FMS or PA interventions can observe what children are doing and instructors can provide immediate feedback, corrections, and reinforcement, once the teacher becomes the parent and the intervention modality moves to a mobile device, it is a challenge to provide this immediate feedback or to fully capture what the parent is doing with their child.

Future research should examine the use of objective activity monitors like accelerometry or pedometry to determine if the child and parent are being physically active during or after using the app, yet this does not provide the context of what activities are being performed during the intervention or if the parent is correctly modeling the motor skill and the child is paying attention and correctly performing the modeled skill. Another option is to ask the parents to film themselves and their child doing the activity bouts. Periodic filming could provide both monitoring of the child's progress through the skill mastery curriculum as well as monitor the parent to measure their implementation fidelity. For example, a coach could evaluate the parents' ability to correctly select the motor skill component for their child to practice, demonstrate the motor skill, demonstrate the prescribed activities, correct the child's errors, and provide positive reinforcement. A coach could reach out with tailored feedback when a parent or child is struggling, or automated feedback could be programed within the app to encourage the parent particularly when specific fidelity metrics are not met. Yet asking parents and children to periodically film themselves is an extra burden, requires coach time and contact points within an intervention, may involve transfer of large data files, and may alter the users' behavior when they know they are filming themselves.

Another future direction to better monitor implementation fidelity in mHealth FMS interventions is to request more self-report data. While self-report data is more subject to bias than objective data, the self-report data could provide additional context about the conditions under which the breaks were conducted. This granular detail on what occurred and preferences for activities may not otherwise be captured from objective app usage data. For example, parents and children selected one star for each day they completed the 12-minute activity bout, but each bout contained five activities. Asking the parent to check off each specific activity they did would provide more granular information on implementation and indicate activities that were too challenging or not preferred. Asking parents to report on space requirements and challenges or facilitators of the activity breaks would provide insight on logistics to help future families who use the app. To standardize duration, parents were asked to use a stopwatch or could use one built into the app to adhere to the 12-minute activity bout, but asking the parent to report on duration of activity bout would measure deviation from the prescribed 12-minutes. Finally, providing the parent with a basic fidelity checklist as is done for teachers and research interventionists may serve as a continuous reminder of how to use the app, adhere to the prescribed activity bouts, and provide ongoing strategies for teaching and encouraging their child.

Digital interventions provide autonomy to the user that is not possible in group-based, in-person interventions common for FMS instruction. For example, for the PLAY study the parent chose what day of the week and time of day they received reminders from the app and when they performed the activity bout with the child; all these reminders were automatically delivered by the app based on the parents' selections. The parents could watch the videos at a convenient time and refer to them or read the accompanying text. The parents had a phone number to reach the research team for technical support, though this was rarely used. While not built into the current version of the PLAY app, there is also opportunity to further tailor the app, such as allowing parents and children to choose among several activities and providing a variety of child-friendly themes, visual graphics, and auditory noises to customize to their preferences. The app could be individualized so that the baseline FMS assessment is programed as a starting point for the child, so that the parent does not need to figure out their child's skill level but rather is prescribed specific skill components based on their child's status. Periodic assessments could be built in that allow the parent or a coach to determine when the child is ready to progress to the next skill component.

Despite these recommendations for improvements, parents and children consistently engaged with the 12-week Motor Skills app and the Free Play app interventions with minimal training, time, or resources. The salience of FMS improvements among children whose parents used the Motor Skills app did not differ by the level of parent fidelity or engagement with the main intervention components. Implementation fidelity was monitored virtually with family-reported daily dosage completed coupled with usage data collected by the app. Despite minimal direct staff involvement during the intervention, the intervention potency, the parental engagement, and the dosage completed were sufficient to produce the desired child motor skills improvements.

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