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An addiction model-based mobile health weight loss intervention in adolescents with obesity

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Summary

Background: Clinical approaches to treating childhood obesity can be expensive and poorly reimbursed, and often produce suboptimal results. It has been theorized that overeating may have addictive qualities, and a sizable number of adolescents with obesity endorse addictive habits. Interestingly, few weight management interventions have tested techniques founded in addiction medicine principles. We therefore performed a pilot study of an addiction model based mHealth weight loss intervention in adolescents.

Methods: Adolescents with obesity were recruited from an multidisciplinary weight management clinic (EMPOWER). Adolescents without significant obesity comorbidities, who exhibited signs of addictive eating, based on the Yale Food Addiction Scale, were enrolled in a pilot study of an interactive, addiction-based, weight loss smartphone app with coaching (http://clinicaltrials.gov: NCT02689154). The app was designed to help subjects omit problem foods, avoid snacking and reduce meal size. A contemporary cohort of adolescents who completed the EMPOWER program were evaluated. Feasibility of recruitment, adherence, retention rates, BMI change and cost of intervention were examined.

Results: Eighteen participants were recruited to app intervention. App participants had higher retention (100% vs. 37%) and lower total cost per patient ($855.15 vs. $1428.00) than the EMPOWER clinic participants. App participants exhibited a significant decrease in zBMI and $\%BMI_{p95}$ over the 6 months ($p < 0.001$ and $p = 0.001$), which was comparable to the age-matched EMPOWER program completers ($p = 0.31$ and $p = 0.06$).

Conclusions: An addiction medicine-based mHealth intervention targeted for adolescents was feasible to implement, resulted in high retention and adherence rates, and reduced zBMI and $\%BMI_{p95}$ in a more cost-effective manner than an in-clinic intervention.

Keywords: Eating addiction, food addiction, mobile health, obesity, paediatrics, weight loss.

Abbreviations: Alanine aminotransferase, (ALT); Body mass index Z-score, (zBMI); Body mass index, (BMI); Coefficient, (coef); Confidence interval, (CI); Functional magnetic resonance imaging, (fMRI); Mobile health technologies, (mHealth); Excess percent over the 95th percentile, ($\%BMI_{p95}$); Quality-adjusted life years, (QALY); Yale Food Addiction Scale for Children, (YFAS-c)

Introduction

It has been theorized that overeating may have addictive qualities (1,2), and there is a growing body of literature which reports that craving for drugs and drive for food involve similar hypothalamic pathways as seen on functional MRI (fMRI) studies (3,4). Recent studies have reported that 5.9–30.7% of adolescents with overweight and obesity enrolled in weight management interventions endorse addictive-like eating habits, similar to the 15–19% reported by adults seeking obesity treatment (5–7). Interestingly, few weight management interventions have tested therapeutic techniques founded in addiction medicine principles

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to date, targeted towards adolescents (5). The notion of obesity as an addictive process in adolescents is controversial, yet this should not preclude evaluating addiction-model methods as a viable intervention strategy.

The general consensus is that clinical interventions for adolescent obesity require intensive management with interdisciplinary teams, frequent visits, and many contact hours (8,9). However, the high prevalence impedes this as a practical strategy to combat obesity (8). Advances in mobile health technologies (mHealth) offer an opportunity to monitor various behaviours, and to deliver interventions in the adolescent's natural environment (10–13). Thus, mHealth platforms may be a cost-saving alternative to an in-clinic intervention for paediatric weight management (14,15).

Pretlow *et al*. (12,16) reported an intervention which applied addiction-based treatment methods to obesity in adolescents, delivered as an iPhone® app. The treatment methods were proposed after analysis of an interactive website for youth with obesity which revealed common themes of food cravings, withdrawal-like symptoms and nervous, habitual eating patterns. The app intervention is founded on three addiction-based principles: (i) divide-and-conquer approach; (ii) staged withdrawal/abstinence; and (iii) body focused repetitive behavioural intervention methods (17). Specifically, the intervention targets three features of addictive eating behaviour: (i) staged withdrawal from participant identified problem foods; (ii) staged withdrawal from daytime snacking between meals; and (iii) withdrawal from excessive amounts of food consumed at meals (17). To date, this app intervention has been tested, as proof of concept, in a self-selected cohort of 43 young people with obesity between 12 and 21 years of age (16). This study recruited youth from newspaper ads and screened volunteers for weight loss motivation and interest in technology. The authors reported that a food withdrawal approach was feasible to implement in this motivated community-based sample (16,17).

We aimed to assess whether this intervention could be a feasible and effective approach for adolescent patients in a health-care setting. We therefore performed a pilot study of the addiction-based, app-mediated intervention in adolescents who were referred to a tertiary care weight management clinic and who self-reported addictive eating behaviours. Our objectives were to assess (i) feasibility of recruitment, (ii) adherence to the intervention components and retention rates to scheduled visits, (iii) effect of the app intervention on BMI Z-score (zBMI) and excess percent over the 95th percentile (%BMI$_{p95}$) and (iv) the cost saving benefits of the app intervention. All the aforementioned objectives were compared to youth who attended at least six visits (program completers) of an in-clinic weight management intervention.

Methods

Recruitment and eligibility

Study procedures were approved by the Children's Hospital Los Angeles (CHLA) Institutional Review Board (http://clinicaltrials.gov: NCT02689154) and were in accordance with the Helsinki Declaration of 1975, as revised in 2008. Participants were recruited for the app intervention from the CHLA multidisciplinary weight management clinic (EMPOWER). Newly referred patients were pre-screened for eligibility prior to their first clinic visit. At the first visit, the Yale Food Addiction Scale for Children (YFAS-c) was utilized to screen for traits of addictive eating (see below) (18–20). Inclusion criteria included age 12–18 years and positive YFAS-c. Exclusion criteria were as follows: obesity co-morbidities (impaired glucose tolerance, diabetes and fatty liver with alanine aminotransferase greater than 45 units/litre, and blood pressure greater than 99th percentile for age, gender and height), known psychiatric illness and/or developmental delay, and the inability to read English.

App enrollment

A total of 50 eligible adolescents were approached to participate in the addiction-based, app-mediated intervention via consecutive enrollment from April 2016 to June 2017. Eighteen adolescents self-selected into the app intervention. Demographic information was collected from all participants (Table 1). Each app participant was supplied with an iPhone® 5S (unless they already owned an iPhone®), a wireless Bluetooth body weight scale (Wahoo Fitness Balance Scale; Wahoo fitness, Atlanta, GA) and a wireless Bluetooth digital food scale (Escali Smart Connect Kitchen Scale, Escali Corp., Burnsville, MN) both of which were interfaced to the app. During the intervention period, the app participants did not attend the EMPOWER intervention. The app program did not require parental involvement.

Comparator group: EMPOWER program completers

A retrospective medical chart review was conducted of 532 unique patients enrolled in the CHLA

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Table 1 Demographic information

	EMPOWER (*n* = 17)	App (*n* = 18)	Difference *P*-value
Gender, *n* (%)			
Female	8 (47.06%)	13 (72.22%)	0.129
Male	9 (52.94%)	5 (27.78%)	
Age (years), mean (± SD)	14.35 (± 1.77)	14.44 (± 1.65)	0.8751
Race, *n* (%)			
Hispanic	4 (23.53%)	11 (61.11%)	0.128
Caucasian	5 (29.41%)	3 (16.67%)	
Black	1 (5.88%)	1 (5.56%)	
Other	7 (41.18%)	3 (16.67%)	
Ethnicity, *n* (%)			
Non-Hispanic	6 (35.29%)	7 (38.89%)	0.826
Hispanic	11 (64.71%)	11 (61.11%)	

EMPOWER Clinic. Participants were seen at the EMPOWER Clinic between January 2014 and July 2016. Participants consented to completion of all measures, including the use of information from their child's medical record for research purposes. Demographic information, such as patient age, gender, ethnicity and insurance status, was abstracted from the patient medical records.

Assessment

Adherence and retention

Data relating to participant performance through the app was tracked remotely and stored on HIPAA-compliant central servers. Data was reported on three key components specific to the underlying addiction model implemented in the intervention: (i) 'problem foods' withdrawal; (ii) snacking elimination; and (iii) food amount reductions at meals (17). Comparator data was extracted from a retrospective database of age matched youth who attended the EMPOWER program between January 2014 and July 2016.

Anthropometric data

Height and weight were assessed at in-person visits at baseline, 3, and 6 months (program completion). Height was measured using a Quick Medical stadiometer, accurate to 0.1 cm (Quick Medical, Issaquah, WA). Weight was measured on a self-calibrating, 500-pound capacity Scale-Tronix 5002 Mobile Stand Digital Scale, accurate to 0.1 kg (Welch Allyn, Skaneateles Falls, NY). Participants wore minimal clothing during the height and weight measurements. BMI was calculated as kilogram per meter squared and BMI Z-score (zBMI) and excess percent over the 95th percentile (%BMI_{p95}) (21) were determined utilizing the CDC growth charts. Efficacy of the app intervention was compared to age-matched EMPOWER youth who completed six or more clinic visits.

Yale Food Addiction Scale – children

The YFAS-c is a validated measure of addictive-like eating behaviour based on the Diagnostic and Statistical Manual of Mental Disorder V diagnostic criteria for substance dependence (18). The scale consists of 25 questions that focus on the seven diagnostic criteria for substance dependence. Participants reporting three or more symptoms and clinically significant impairment were considered to have met the criteria for addictive eating habits (2,22).

Interventions

EMPOWER intervention:

The EMPOWER clinic consists of a team of physicians, dietitians, physical therapists and psychologists who administer the EMPOWER intervention in a clinic setting. Treatment is administered over monthly clinic visits (averaging 100 min at the initial visit and 80 min per follow up visit, ~8 contact hours per participant per 6-month intervention period). During each EMPOWER visit; patients are evaluated by the team. Providers rotate through individually, obtaining history and assessing patients based on their discipline. Individualized behaviour change goals for healthy eating, physical activity, emotional well-being and family support are then followed up at subsequent monthly visits. The behavioural treatment

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strategies adopted in the EMPOWER intervention do not address eating as an addiction or incorporate addiction-based therapeutic targets into the treatment model.

App intervention

The specific details of the addiction model obesity intervention have been described by Pretlow *et al*. (16) Briefly, the intervention was implemented through an iPhone® app called W8Loss2Go©, which was securely integrated with a network-server for real-time data access and storage (16). The intervention included two clinic visits at 3 and 6-month intervals (45 min per visit), text messages 5 days per week (2 min/SMS = 240 min), weekly phone sessions (15 min × 24 sessions = 360 min), for a total of ~11.5 contact hours per participant per 6-month intervention period. The intervention targets three features of addictive eating behaviour: (i) staged withdrawal from participant identified problem foods; (ii) staged withdrawal from snacking between meals; and (iii) withdrawal from excessive amounts of food consumed at meals (16). Problem foods were defined as specific foods for which participants felt they had cravings or difficulty resisting. Participants sequentially withdrew from two self-selected problem foods at a time, with the goals of total abstinence from the food for a minimum of 10 days in a row, plus cravings resolution (16). Consumption of a problem food during or after this 10-day period would result in a re-start of the abstinence period.

After withdrawing from two problem foods, participants would start the second phase of eliminating snacking by choosing time periods to avoid snacking (i.e. morning, afternoon, evening or nighttime). Once the participant had abstained from snacking during their chosen time interval for 10 days, the participant then chose additional time intervals to abstain from snacking, with the overall goal of eliminating snacking between meals for the entire day. After snacking was eliminated from one time period, the third stage would commence and excessive food amounts at meals were targeted. Each participant weighed and recorded typical serving amounts of all foods at meals in the app. At subsequent meals, when a recorded food was served again the app reduced amounts of each food (decrease of 2% per food item) and the participant weighed out and ate only those amounts. If weight loss had not occurred within 4 days, the app further reduced all logged food amounts in 2% increments, until weight loss ensued. Participants took photos of meals via the app, post weighing, which were reviewed by the mentor (APV) weekly, to allow for external confirmation of amount reduction. After the participant had eliminated at least two problem foods, stopped snacking in one time period and started weighing their foods at meals, they continued to interact with all three phases for the remainder of the intervention period. In addition, participants had access to the app home page, which included various addiction model strategies, including motivation, distraction ideas and coping skills techniques (16).

Participants were asked to weigh themselves daily and participate in weekly phone meetings with the mentor. Two 45-minute face-to-face meetings were held at month 3 and 6. Participants were sent daily text messages from their mentor. The mentor utilized a motivational interviewing paradigm to interact with the participants (23) and an electronic system within the app database to document each encounter.

The first four recruited participants received financial compensation of three hundred dollars upon completion of the study. The app was then upgraded to include a point accrual system in which the active (n = 8) and newly recruited (n = 6) participants earned points as they completed specific tasks, which were associated with a dollar amount, up to three hundred dollars over the course of the intervention.

Feasibility outcomes

Recruitment rate, calculated as the proportion of those eligible participants who were consented into the app intervention, was assessed upon completion of the recruitment period. A short semi-structured interview was conducted with all eligible participants, during which they were asked how they felt about the recruitment process. For those participants who declined to participate in the app intervention they were asked about their reasons for not participating.

Clinical outcomes

The primary clinical endpoints were mean change in zBMI and $\%BMI_{p95}$ measured at baseline, 3 and 6 months. Excess BMI percent over the 95th percentile (BMI percentile – 95th percentile) is the distance (in kg/m^2) from the 95th percentile and may be a more accurate metric of weight status in adolescent with obesity (21). Secondary clinical endpoints measured at the same time points, were (i) adherence with the app intervention components, (ii) compliance with scheduled weekly phone calls, (iii) compliance with in-clinic visits and (iv) YFAS-c score at baseline and 6 months. Although primarily a pilot feasibility study, we compared BMI changes between the app intervention and age-matched EMPOWER comparator group.

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Cost analysis

An estimated cost analysis was completed to determine the cost per patient to implement the 6-month app intervention, as compared to the EMPOWER intervention. Provider responsibilities, requirements and associated costs are outlined in Table S2. The mentor staff cost was comparable to the national average clinical research coordinator's annual salary of $56 589 per year (glassdoor.com). The all-staff costs per patient were calculated for the EMPOWER intervention, including the provider-cost for each multidisciplinary provider (Table 2).

Methods of data analysis

Descriptive statistics were used to summarize and describe the distribution of the variables. Continuous variables were summarized as mean and standard deviation for normally distributed, whereas, median and inter-quartile range for non-normally distributed. Categorical variables were summarized as frequencies and percentages. Generalized estimating equation linear model was used to examine changes in zBMI and $\%BMI_{p95}$ from baseline to 6-months follow-up. The results are summarized as coefficient estimate with 95% confidence interval and *p*-value. (Stata Intercooled 13.1, College Station, Texas).

Results

Of the 50 eligible adolescents approached, 18 elected to participate in the app intervention (Fig. 1). As this

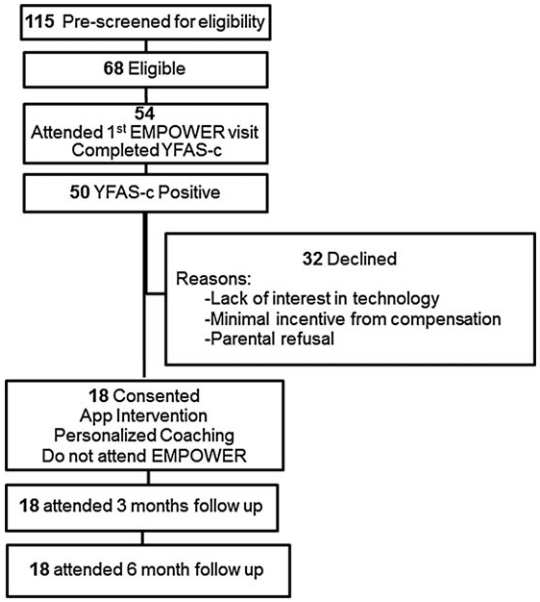

Figure 1 CONSORT diagram.

was a pilot study, the sample size was small, and the self-selection process resulted in a recruitment rate of 36%. The 32 youth that declined to participate cited lack of interest in technology, minimal incentive from financial compensation and parental desire for intensive monthly visits as reasons for refusal (Fig. 1). In the EMPOWER comparator group, 532 unique patients with 1759 clinic visits were evaluated. There were 95 program completers (17%), while 156 (31%) attended only one visit. Seventeen of the program completers were ages 13–18. The characteristics of

Table 2 Cost analysis for 6-month app intervention compared to EMPOWER in-clinic intervention

	Estimated cost/patient/6-month intervention			
	App intervention		EMPOWER	
Total # of encounters	3		6	
	Per encounter	Per patient	Per encounter	Per patient
Provider staff *	$21.00	$77.00	$136.59	$819.50
Ancillary staff+	--	--	$44.09	$260.50
Facility fee	$50.00	$150.00	$50.00	$300.00
Additional contact	--	$224.00	--	--
Provider training	--	$6.22	--	$47.78
Data server	--	$5.75	--	--
App maintenance	--	$10.57	--	--
Compensation	--	$300	--	--
Body/food scale	--	$81.61	--	--
Smart phone + data plan^	--	$156.67	--	--
Total cost	$1011.82^		$1427.78	

*EMPOWER provider staff includes: physician, psychologist, physical therapist and dietitian.
+EMPOWER axillary staff includes: clinical coordinator, administrative coordinator and medical assistant.
^Equipment cost if participant did not own smart phone: $282/patient. This cost includes purchase of an iPhone 5S and a 6-month business, group data plan.

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the study cohort are shown in Table 1. Mean age of participants was 14.4 years (range, 12.3–17.9). The female to male ratio, racial/ethnic distribution, zBMI at baseline, and government insurance rates were comparable between the app group and the EMPOWER program completers.

Adherence

Retrospective analysis of patients who participated in the EMPOWER program from 2014 to 2016 revealed a retention rate of 35% at 6-month follow-up (Fig. 2A). In comparison, 100% of the app intervention group attended all scheduled face-to-face visits, and 72% (13/18) participated in at least 80% of the scheduled phone meetings. Further, app participants interacted with the app 1–8 times per day (3.23 daily average) and spent 4 min 29 s daily in the app.

The majority of the participants in the app group withdrew from at least five problem foods (14/18, 78%), and reduced (16/18, 89%) or completely eliminated (10/18, 55%) snacking. By completion of the study, 44% (8/18) of participants were weighing at least 50% of their meals each day, resulting in an average meal size reduction of 40%. Participants reported that 72% of their 'not weighed' meals were due to eating outside the home.

There was no significant difference in zBMI changes ($p = 0.66$) or adherence ($p = 0.5$) between participants enrolled before and after implementation of the points system. However, the engagement in consistent weighing of food at meals increased by 15% ($p = 0.04$).

BMI z-score

Subjects enrolled in the app group experienced a significant decrease in zBMI over time (coefficient (coef) = −0.02, 95%CI = −0.03, −0.01, $p < 0.001$, Fig. 2B) with a decrease noted at 1 month (coef = −0.05, 95%CI = −0.07, −0.02, $p < 0.001$), 3 months (coef = −0.07, 95%CI = −0.11, −0.03, $p < 0.001$) and 6 months (coef = −0.09, 95%CI = −0.13, −0.05, $p < 0.001$) compared to baseline. App participants exhibited a comparable decline in zBMI from baseline to 6-month follow-up compared to EMPOWER program completers (coef = −0.02, 95%CI = −0.04, 0.01, $p = 0.316$

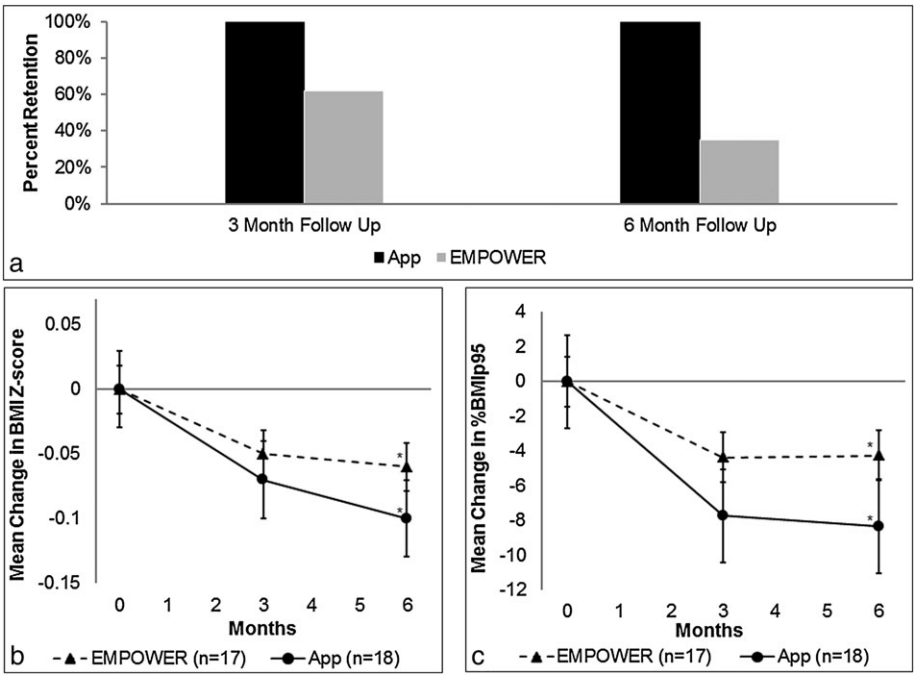

Figure 2 A. Attendance at scheduled face-to-face visits at 3 and 6 months of App (black bars) and EMPOWER (grey bars) participants. B. Mean change in BMI Z-score across intervention period between App (black circles) and EMPOWER (black triangles). Data represent mean ± stdev changed compared to baseline (* $p < 0.001$). App participants exhibited a comparable decline in zBMI from baseline to 6 month follow up compared to EMPOWER (coef = −0.02, 95%CI = −0.04, 0.01, $p = 0.316$). C. Mean change in %BMIp95 across intervention period between App (black circles) and EMPOWER (black triangles). Data represent mean ± stdev changed compared to baseline (* $p < 0.001$). App participants exhibited a comparable decline in %BMIp95 from baseline to 6-month follow-up compared to EMPOWER (coef = −2.04, 95%CI = −4.16, 0.08, $p = 0.059$).

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Fig. 2B). At the end of the 6-month intervention, subjects in the app group exhibited an average −2.2 kg (−10.2 to +5.1 kg) weight change compared to a −1.7 kg (−6.2 kg to +8.1 kg) weight change in the EMPOWER group. There was no ethnicity effect (Hispanic compared to non-Hispanic) on zBMI (coef = 0.07, 95%CI = −0.14, 0.28, p = 0.503). Similar patterns were observed with the $\Delta\%BMI_{p95}$ in the app group (Table S1).

YFAS-c

Ninety-three percent of the 54 youth screened for app study enrollment scored positive on the YFAS-c. The majority of the app group (10/18, 55%) scored 4 or more on the YFAS-c at baseline, indicating significant addictive eating. While the study was not designed to evaluate changes in YFAS-c symptoms, we administered follow-up YFAS-c to all app participants at the six month follow up visit. In post-hoc analysis, there was no significant linear relationship between the change in zBMI at 6 months and the YFAS-c score at baseline (coef = 0.01, 95%CI = −0.02, 0.04, p = 0.52). Of note, 17% (3/18) of app participants had negative YFAS-c scores upon completion of the intervention.

Cost analysis

A cost-analysis was performed to calculate the per patient implementation costs between groups for a 6 month intervention (Table 2 and Table S2). The app intervention cost $855.15 for a participant who already owned a smart phone (10 out of 18, 55%), per 6 months, and decreased the zBMI by 0.10. For the 45% of youth who did not own a smartphone, the intervention cost was $1011.82 ($282/patient for an iPhone5S and 6 month data coverage plan). By comparison, on average completion of the EMPOWER intervention decreased the zBMI by 0.06, and cost more, $1427.78 per patient per 6-month in-clinic intervention. A proportion of these expected costs would be recovered under current standard billing codes.

Discussion

We report herein that an addiction model-based mHealth weight loss intervention for adolescents was feasible to administer in a tertiary care weight loss setting. The intervention was associated with high retention and adherence rates and resulted in modest but significant improvements in obesity over a 6 month period, comparable to youth who completed an in-clinic intervention, with lower cost than a traditional multidisciplinary approach. Remarkably, although there are many freely available mHealth technologies which address behaviour change, few employ addiction principles, including withdrawal response and tolerance, and even fewer are targeted towards children (1,20,21). Thus, coupling addiction medicine principles with mHealth approaches may improve the effectiveness of similar interventions.

Two common barriers to implementing innovative weight loss interventions, especially in adolescents, is the difficulty in recruitment and sustained engagement. The recruitment rate of this study was 36%, demonstrating the potential difficulty of recruiting eligible youth into weight management studies. Incentivized, mHealth-based interventions may provide a more attractive option for this population than traditional in-clinic interventions and requires further investigation.

In addition, a recent meta-analysis revealed that the majority of mHealth weight loss interventions targeted for youth did not maintain sustained engagement during the intervention with only 39% of individuals utilizing a weight loss app for more than 10 interactions (10,14). In contrast, participants in the current study used the app on average more than 500 times, over the 6-month period. There are multiple factors that may have resulted in improved app usage in this study, including personalized coaching, daily text messages, app-generated daily reminders and financial incentive. Personalized coaching is likely to impact both traditional and mHealth weight loss interventions (24–26). Given these findings, it is not possible to estimate how much of the engagement and efficacy of the app intervention was due to the coaching component vs. the app itself.

Another major benefit of mHealth approaches is the potential for cost savings. Our estimated-cost analysis revealed that although the app intervention cost more than routine care management, it was cheaper than a multidisciplinary weight loss intervention. This does not include the decreased burdens placed on patients and families who do not have to miss work/school and travel to in-person visits. Currently, obtaining insurance coverage for mHealth interventions can be difficult; however, a strong argument can be made for payer's potential cost savings through implementing these interventions in clinical practice.

Limitations

Although these results are encouraging, there are limitations to interpreting them as they arise from a small,

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time limited, pilot study. Our recruitment strategy, without randomization, may have selected more motivated patients, or those more open to mobile health interventions. The study was not designed to test efficacy of the addiction intervention alone on weight loss; however, by utilizing a convenience comparator sample from EMPOWER program completers, we were able to report how the complete intervention package (app plus coaching) affected weight trends compared to adolescents who adhered and completed an in-clinic intervention. Compared to program non-completers, those youth who completed the EMPOWER program were predominantly male, with lower reported rates of anxiety and depression in one or more parent; these differences must be recognized when evaluating the results. Furthermore, the app intervention was time limited, with no weight maintenance phase included. Therefore, while these results are promising, further randomized and longer-term investigations are required to evaluate the efficacy of both the addiction intervention itself and the mHealth component on weight loss and maintenance.

App participants received substantial financial incentives for participation. Financial incentives improve adherence and outcome of obesity interventions (26) and thus likely contributed to the success of the app intervention group. The coaching component for this study was implemented by only one mentor (APV). Patient retention and efficacy could vary with different mentors. Standardized curricula and protocols could be utilized to train mentors and evaluate the effect of having multiple coaches on participant's weight status. Despite these limitations, our study provides important formative feedback for the development of future randomized controlled trials of addiction model based mHealth weight loss interventions in paediatrics.

Conclusions

Findings from this pilot study suggest that youth that participated in an addiction model-based mHealth intervention targeted towards adolescents had high retention and adherence rates and modest but significant improvements in obesity over a 6-month intervention. This approach may be as effective as completion of a traditional multidisciplinary in-clinic weight management intervention, at a lower cost.

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Conflict of interest statement

Dr Pretlow is the CEO of eHealth International, Inc. and owner and developer of the app used in the study. The additional authors (Vidmar, Borzutzky, Wee, Fox, Fink and Mittelman) have no financial relationships or conflict of interest relevant to this article to disclose.

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Contributors' statements

Drs Vidmar, Mittelman, Pretlow and Borzutzky conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript.

Ms Wee performed the statistical analysis, helped draft the initial manuscript, helped interpret results, critically reviewed and revised the manuscript.

Dr Fox assisted with the cost analysis evaluation and modelling and critically reviewed and revised the manuscript.

Ms Fink assisted with the conceptualization, design of the study and critically reviewed and revised the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Change in BMI Z-score and percent over the 95th percentile (%BMI_{p95}) across intervention period during App intervention compared to EMPOWER cohort.

Table S2. App provider-related requirements, responsibilities and cost.

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