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ORIGINAL ARTICLE

Pediatric Obesity

Cost-effectiveness of a motivational interviewing obesity intervention versus usual care in pediatric primary care offices

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Abstract

Objective: This study aimed to assess the incremental cost-effectiveness ratio (ICER) of a 2-year motivational interviewing (MI) intervention versus usual primary care.

Methods: A national trial was implemented in the Pediatric Research in Office Settings (PROS) network of the American Academy of Pediatrics to evaluate MI versus usual care for children (2-8 years old; baseline BMI 85th-97th percentiles). Health care use, food costs, provider fees, and training costs were assessed, and sensitivity analyses were conducted. Primary outcome was the ICER, calculated as cost per unit change in BMI percentile for intervention versus usual care.

Results: At 2 years, 72% of enrolled parent/child dyads were retained; 312 children were included in the analysis. Mean BMI percentile point change was −4.9 and −1.8 for the intervention and control, respectively, yielding an incremental reduction of 3.1 BMI percentile points (95% CI: 1.2-5.0). The intervention cost $1051 per dyad ($658 for training DVD development). Incorporating health care and non-health care costs, the intervention ICER was $363 (range from sensitivity analyses: cost saving, $3159) per BMI percentile point decrease per participant over 2 years.

Conclusions: Training pediatricians, nurse practitioners, and registered dietitians to deliver MI-based interventions for childhood obesity in primary care is clinically effective and acceptably cost-effective. Future work should explore this approach in broader dissemination.

INTRODUCTION

Obesity is a public health problem associated with multiple comorbidities and significant social and economic costs [1–3]. Although a large proportion of the sequelae and associated costs of obesity occur during the adult years, a number of comorbidities emerge during childhood that result in higher health care costs among children with obesity than among their healthy weight peers [4–10]. It is imperative to find cost-effective ways to address obesity.

Primary care providers, including pediatricians and nurse practitioners, represent the front line of pediatric obesity prevention and treatment. Expert Committee Recommendations endorsed by the American Academy of Pediatrics outline a staged treatment approach starting in the primary care setting prior to considering other more intensive and presumably more expensive and less convenient options such as referral to multidisciplinary care [11].

Although few primary care initiatives have proven successful in treating pediatric obesity, a prior trial (the Brief Motivational Interviewing to Reduce Child BMI [BMI^2 intervention]), showed statistically and clinically significant decreases in body mass index (BMI) over 2 years among children 2 through 8 years of age (at baseline) [11–13]. The BMI^2 study, described in detail elsewhere [13,14], was a three-arm trial designed to test two approaches to motivational interviewing (MI) compared with a usual care control arm. Briefly, all participating primary care pediatricians and nurse practitioners (hereafter described as PCPs) along with one staff person per clinic received a half-day study orientation session, which included an overview of current treatment guidelines. One intervention arm included pediatricians and registered dietitians (RDs) (the "PCP/RD intervention" group), and both received an additional 1.5 days of in-person training in MI and behavior therapy as well as an interactive MI DVD training system focusing on pediatric obesity developed for this study. Children in the PCP/RD intervention group were offered four in-person counseling sessions delivered by PCPs over 2 years plus six MI-based counseling sessions (by phone or in person) with RDs over the 2 years [13,14]. The other intervention arm was a PCP-only intervention group that received visits with the MI-trained PCPs, without RD visits. The PCP/RD intervention led to a statistically and clinically significant mean reduction in BMI compared with those who received usual care [13]. Meanwhile, there were no statistically significant differences in BMI outcomes between the PCP-only group and the usual care control participants, which is likely because of an insufficient dose of the intervention [13]. Therefore, as the PCP-only intervention was dominated by usual care, only the PCP/RD intervention is included in this cost-effectiveness analysis [13].

In an effort to inform the process of improving the treatment of obesity in pediatric primary care and to assist decision-makers faced with the allocation of funds related to pediatric obesity, the objective of this analysis was to evaluate the incremental cost-effectiveness ratio (ICER) of the BMI^2 intervention from a societal perspective over a 2-year period, comparing the PCP/RD intervention group with a concurrent usual care group. The societal perspective aims to include a broad array of costs beyond those associated with health care (e.g., productivity costs, including time away from work, and consumption costs, including food costs) [15].

Study Importance

What is already known?

- Obesity is a public health problem that is associated with significant social and economic costs. Prior work has largely focused on costs associated with tertiary care treatment and community-based interventions. Little is known about the costs and cost-effectiveness of interventions to address childhood obesity in the primary care setting.

What does this study add?

- This study presents the costs and incremental cost-effectiveness ratio, from the societal perspective, of the Brief Motivational Interviewing to Reduce Child BMI primary care intervention. It shows that this approach is effective and associated with low costs and incremental cost-effectiveness ratio, taking a societal view (i.e., including costs such as food).

How might these results change the direction of research?

- Further work should explore dissemination of brief motivational interviewing training for primary care providers and registered dietitians to reduce BMI in children.

METHODS

Child anthropometrics and parent-reported survey data were collected as part of the 2-year national randomized controlled trial to test the use of MI versus usual care among the parents of children who, at baseline, were 2 through 8 years old and who had BMI measurements between the 85th and 97th percentiles for age and sex (Centers for Disease Control and Prevention) [16]. All practices were recruited from the Pediatric Research in Office Settings (PROS) network (www.aap.org/pros), the primary care practice-based research network of the American Academy of Pediatrics. The design of this intention-to-treat analysis included 645 total parent/child dyads in all three groups of the study at baseline, with a total of 457 dyads (71%) followed to study conclusion at the end of 2 years. The usual care control group included 11 practices (n = 198 parent/child dyads, with 158 dyads [80%] retained), and the PCP/RD group included 15 practices (n = 235 initial dyads, with 154 dyads [66%] followed to study conclusion). Thus, for these two groups (PCP/RD and usual care), 312 (72.1%) of the original 433 dyads were retained at 2 years and were included in this analysis (even if participants did not have complete data at all time points). Of note, this degree of attrition was not unexpected. Attrition from pediatric weight management interventions, which are typically 3 to 12 months long, ranges from 27% to 73% [17].

For the BMI^2 study, the overall attrition rate was 29% over 2 years. As the study occurred during implementation of the Affordable Care Act, participants could have had changes to their insurance coverage or their families may have faced challenges in continuing care with the same PCPs.

Ethics approval for the clinical trial was obtained from the University of Michigan and the American Academy of Pediatrics. All parents gave written informed consent for their and their child's participation.

For this study we conducted a cost-effectiveness analysis, which is a way to consider the marginal cost (in monetary terms) and the marginal benefit (expressed as natural units, BMI units in this case) of an intervention in comparison to an appropriate alternative [18]. To

TABLE 1 Overview of variables used in the analyses for this study

Input variable	Source	Data obtained	Other source of cost data	Analyses in which cost is included	Converted to annual costs
Costs to family for dining out costs	Annual parent survey	Weekly estimate		SPI; SPUC; SSI; SSUC	× by 52
Costs to family for groceries	Annual parent Survey	Weekly estimate		SPI; SPUC; SSI; SSUC	× by 52
Out-of-pocket costs to family for index child's prescriptions	Annual parent survey	Monthly estimate		SPI; SPUC; SSI; SSUC; HCPI; HCPUC	× by 12
Number of ED visits by index child	Annual parent survey	Annual estimate	MEPS	SPI; SPUC; SSI; SSUC; HCPI; HCPUC	# of visits × cost estimate from MEPS
Number of sick visits by index child for new problems	Annual parent survey	Annual estimate	MEPS	SPI; SPUC; SSI; SSUC; HCPI; HCPUC	# of visits × cost estimate from MEPS
Number of sick visits by index child for chronic problems	Annual parent survey	Annual estimate	MEPS	SPI; SPUC; SSI; SSUC; HCPI; HCPUC	# of visits × cost estimate from MEPS
Number of visits by index child for checkups	Annual parent survey	Annual estimate	MEPS	SPI; SPUC; SSI; SSUC; HCPI; HCPUC	# of visits × cost estimate from MEPS
Number of days of missed work by parent(s) for other medical visits for index child	Annual parent survey	Annual estimate	BLS hourly wage data	SPI; SPUC; SSI; SSUC	# of hours missed × mean hourly wage from BLS
Number of days of missed work for study-related visits for index child	Study admin data[a]	Number of in-person study visits recorded	BLS hourly wage data	SPI; SPUC; SSI; SSUC	# of hours missed × mean hourly wage from BLS
Incentives	Study admin data[a]				
Reimbursement to practitioner/ practice	Study admin data[a]			SPI; SPUC; SSI; SSUC; HCPI; HCPUC	
Reimbursement to RDs	Study admin data[a]			SPI; SSI; HCPI	
Costs to the study to train PCPs and staff	Study admin data[a]			HCPI, HCPUC	
Costs to the study to develop study training DVD	Study admin data[a]			HCPI	

Abbreviations: BLS, Bureau of Labor Statistics; ED, emergency department; HCPI, health care perspective for intervention group; HCPUC, health care perspective for usual care group; MEPS, Medical Expenditure Panel Survey; PCP, primary care provider; RD, registered dietitian; SPI, societal perspective for PCP/RD intervention; SPUC, societal perspective for usual care; SSI, steady state for intervention group; SSUC, steady state for usual care group.
[a]Study admin data: Refers to documentation by the research team of study-related expenses and number of visits attended by participants.

achieve this, we calculated the ICER. The ICER provides a measure of additional cost for each additional unit gain of effectiveness delivered by the intervention [18]. The ICER was calculated as cost per unit change in age- and sex-specific BMI percentile from baseline to 2-year follow-up. Survey data collected at baseline and at the end of years 1 and 2 included the following items regarding costs:

a. Parent-reported health care use for the child over the previous 12 months, including out-of-pocket prescription costs, health care visits, and missed work related to health care encounters of any kind (example question: "Over the past 12 months about how many of the following health care visits has your child had: emergency department visits, sick visits for a new illness or problem, sick visits for a chronic illness or problem, checkup visits not including visits for this study"). Categorical response choices were provided only in one instance (for out-of-pocket prescription medications) to assist respondents in estimating broad strata of their cost burden. No tools were provided to aid recall and no electronic records were used to capture costs. Parent reports of patients' health care visits were used to calculate health care use costs.
b. Parent-reported food costs (including dining out costs, grocery costs) were collected via open ended questions asked annually (i.e., In a typical week how much do you spend on groceries for the whole household? $__________; of note, no cost strata were provided).

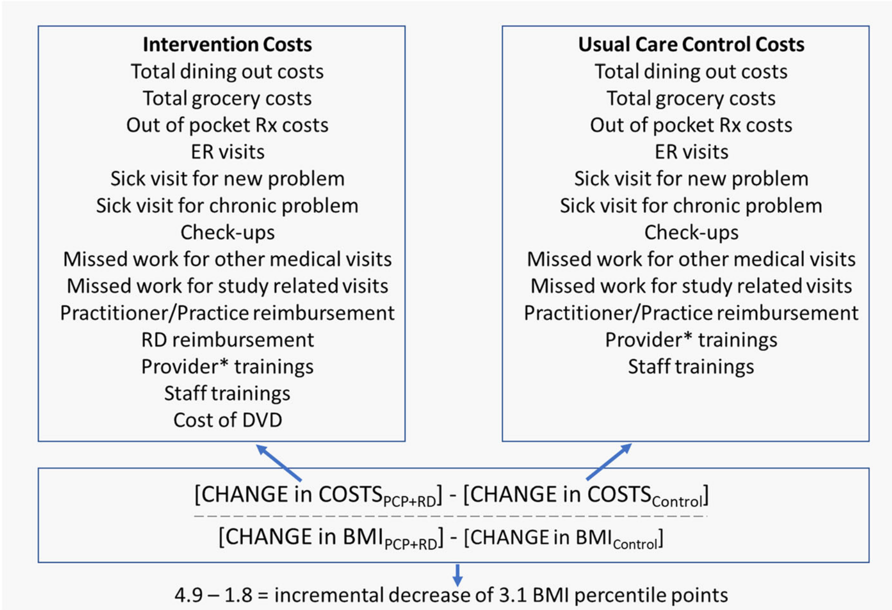

FIGURE 1 Cost analysis equation with societal view. *For usual care group, PCPs = pediatricians/nurse practitioners; for intervention group, PCPs = pediatricians and registered dietitians (RDs). ER, emergency room

In addition, missed work for study-related visits was assessed using attendance records for in-person PCP and RD sessions. PCP and RD reimbursement amounts were obtained from administrative study data. Furthermore, costs of educating PCPs in MI to deliver the intervention (including costs of in-person training and costs of producing the training DVD) were calculated. The costs included in each analysis are indicated in Table 1.

The measure of efficacy, mean change in age- and sex-specific BMI percentile points from baseline to 2-year follow-up, was obtained from a mixed-effects regression with children nested within their practice to control for cluster randomization effects. The study was powered to detect a 3-point difference in BMI percentile between groups, with an assumed standard deviation for BMI percentile between 4 and 6: power of 0.80 and 2-tailed α of 0.05 [13]. For this cost analysis we included only those participants for whom we had cost data and used all available data (even if they did not have complete cost data for each time point).

The ICER for the PCP/RD intervention compared with usual care was calculated using the equation in Figure 1.

Annual expenditures for eating out and for groceries were calculated from the survey data for the year before baseline, for year 1 and for year 2. The difference between the annual costs for year 1 compared with the baseline year was calculated and similarly the difference between the year 2 costs and baseline was calculated. These costs were summed to represent dining out and grocery costs per participant over the 2-year intervention.

As noted, monthly out-of-pocket prescription costs were collected from survey data at baseline and at the end of years 1 and 2. Parents selected their perceived cost burden for prescriptions from the following strata: $0, $1 to $30, $31 to $60, $61 to $90, and more than $90 per month. We used the midpoints of these strata ($0, $16, $46, $76, $90) to estimate the out-of-pocket monthly costs for parents. Differences from baseline were calculated as described earlier.

Emergency visits, sick visits for new problems, sick visits for chronic problems, and routine checkups (excluding study visits) were summed and averaged over the number of respondents at each time point to obtain the mean number of visits in the previous 12 months in each study group. To obtain a cost estimate for use frequency in each setting, the number of visits was then multiplied by national expenditure data from the 2013 Medical Expenditure Panel Survey (MEPS) [19]. To account for wages related to missed work among parents as they accompanied their children to medical visits and study-related visits, the visit frequencies (from parent self-reported medical visits and from data collected regarding in-person study visit attendance) were multiplied by the average hourly wage plus 30% for fringe benefits $\times$ 4 hours (corresponding to a half-day of missed work per visit) based on 2013 Bureau of Labor Statistics data for all occupations (thus these estimates were not profession specific) [20]. These values were aggregated to reflect costs per participant per 2 years of intervention. Finally, all cost data (both for our study and for all referenced studies) were adjusted for inflation to 2019 US dollars. We used personal consumption expenditure indexes available from the Bureau of Economic Analysis [21] to inflate dining costs, grocery costs, and health care visit costs. Out-of-pocket costs and time costs were inflated using the Consumer Price Index for medical care [22]. Discounting (which is a way to make comparisons when dealing with cost-effectiveness analyses that span a long period of time) was not used owing to the duration of the study (2 years).

We estimated the ICER from the societal perspective and, therefore, included variables that would pertain to the implementation of the intervention in real-world settings that consider food costs and parents' missed work, in addition to expenditures for medical encounters and prescriptions. Transit costs were not included as data on zip codes were not available. Families received a $20 gift card and small toys at baseline and again at the 1-year height/weight measurement. At the 2-year measurement, they received a $20 gift card. The total value of their incentives totaled approximately $96 per family. PCPs received $50 for each in-person MI visit; RDs received $35 for each phone visit.

To address potential uncertainty regarding the costs assessed in this study, we conducted a one-way sensitivity analysis to examine uncertainty one factor at a time (using the lower and upper bounds of year 2 to year 0 change). The factors, varied one at a time, were the following: dining costs, grocery costs, out-of-pocket prescription costs, number of ER visits, number of new sick visits, number of chronic sick visits, checkup visits, number of missed workdays (study-related), and number of missed work-days (other). Furthermore, we conducted a probabilistic sensitivity analysis, which allowed us to vary multiple variables at the same time using random draws from each of the distributions and to obtain percentile-based 95% confidence intervals (CI) for the ICER. From these calculations, a cost-effectiveness acceptability curve was generated. All analyses were preformed using Stata/SE version 15 (StataCorp LLC) and TreeAge Pro version 2021 (TreeAge LLC).

RESULTS

Sample description

This analysis was performed on data from 312 participants, 158 in the usual care control group and 154 in the PCP/RD group, for whom baseline and 1-year and 2-year follow-up BMI data were complete. The largest proportion of the cohort was White (60% White, 22% Hispanic, 7% Black, and 6% Asian), and approximately two-thirds (68%) reported an annual household income at or above $40,000. Details of the sample have been previously reported [13,14].

Effectiveness of the MI intervention - Change in BMI percentile

There was a mean reduction in BMI for both the MI intervention (PCP/RD) and the control (usual care) groups, but the reduction for the MI intervention group was statistically significantly larger than for the control group (4.9 vs. 1.8; $p = 0.02$). The net difference between these groups was 3.1 BMI percentile points (95% CI: 1.2-5.0) [13].

Costs

The cost of the PCP/RD intervention (i.e., training costs for PCPs and clinic staff, not including incentives for children/families or PCPs or practice/practitioner reimbursements) per participant for 2 years was $1,051. This included the cost to produce the training DVD, which was $154,700 ($658/participant) and constituted 63% of the overall direct costs related to the intervention. Given that the training DVD has already been produced and is available for continued use, cost-effectiveness was calculated with and without DVD costs. The average costs for usual care visits reported by parents were $146 per participant. Changes in average health care costs (including study-related visits) and societal costs (i.e., food and missed work for medical visits) after 2 years of the study compared with costs reported at baseline (for the year prior to study enrollment) for children enrolled in the PCP/RD intervention group were $2,013 and for the usual care group were $886 (Table 2). Of note, for the intervention group the eating out costs decreased while grocery costs increased.

TABLE 2 Costs of BMI[2] intervention over 2-year study period, per participant

Differences in aggregate yearly costs per participant (year 2 versus baseline year)	Usual care group ($n = 158$)	PCP/RD intervention group ($n = 154$)
Dining out costs	$345.65	−$473.23
Grocery costs	$973.39	$1528.02
Out-of-pocket Rx costs	−$43.68	−$43.43
ER visits	−$140.93	−$235.32
Sick visits for new problem	−$353.42	−$644.67
Sick visits for chronic problem	−$90.87	−$323.67
Checkups	−$58.71	$119.37
Missed work: other medical visits	−$66.47	−$57.98
Missed work: study-related visits	−$4.04	$496.81
Costs of study-related payments		
Practitioner/practice reimbursement	$179.75	$425.39
RD reimbursements		$171.12
Costs of educational program		
PCP trainings.[a,b]	$101.85	$280.15
Staff for trainings	$43.87	$112.25
Costs of DVD production		$658.30
TOTAL	**$886.38**	**$2013.11**

Note: Data represent differences in aggregate yearly costs per participant (year 2 vs. baseline year).
Abbreviations: ER, emergency room; PCP, primary care practitioner; RD, registered dietitian.
[a]Includes expenses for roundtrip airfare, hotel rooms, miscellaneous travel expenses, and meals/snacks at hotels for PCPs/RDs who underwent training, distributed across all children in the intervention group.
[b]For usual care group, PCPs = pediatricians/nurse practitioners; for intervention group, PCPs = pediatricians and registered dietitians.

ICER

From a societal perspective that accounts for the costs of parents' self-report of missed work (for medical visits and study visits), the ICER of the intervention compared with usual care was $363 per BMI percentile point decrease, per participant, over 2 years. Considering a health care perspective (i.e., not considering costs for food or missed work), the ICER of the intervention compared with usual care was $284 per percentile point decrease in patient BMI, per participant, over 2 years (range: $50-$1,553). When excluding costs of DVD production and

TABLE 3 Probabilistic sensitivity analysis

	DVD costs	Base case ICER	95% CI	
BMI percentile	With DVD	$363	CS	$3159
	Without DVD	$151	CS	$2454
Excluding training cost	With DVD	$284	CS	$2809
	Without DVD	$72	CS	$2276

Abbreviations: CS, cost saving; ICER, incremental cost-effectiveness ratio.

other training costs, the ICER for the steady state was $72 per BMI percentile point decrease, per participant, over 2 years (Table 3).

Sensitivity analyses

The results of the one-way sensitivity analysis are presented in Figure 2A,B. The change in grocery costs impacted the ICER the most, followed by parent-reported dining costs, number of checkup visits, and number of missed workdays due to study-related visits. The results of the probabilistic sensitivity analysis for the ICER with DVD cost included are presented in Table 3 and they show a range from cost saving (i.e., a negative value) up to a cost of $3159 per BMI percentile unit change. For the ICER without DVD cost, the range was cost saving to a cost of $2276 per BMI percentile unit change. The cost-effectiveness acceptability curve (Figure 3) indicates that for low willingness to pay the usual care strategy is more acceptable than the intervention.

DISCUSSION

Our analysis suggests that the BMI^2 intervention in primary care settings costs $1,051 per participant over 2 years and that it has an ICER of $363 per percentile point decrease in patient BMI per participant over 2 years when considered from the societal perspective and $284 from the health care perspective. Excluding the development and

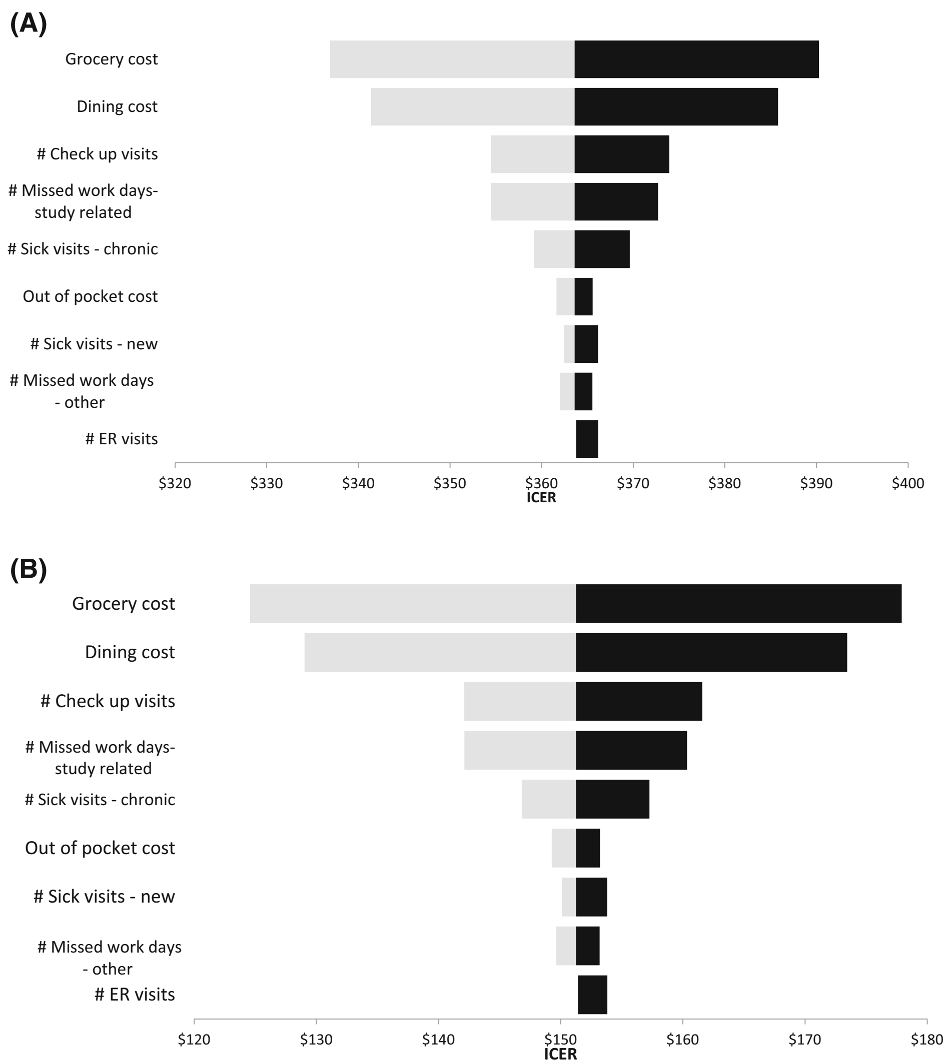

FIGURE 2 (A) Tornado diagram for one-way sensitivity analysis: *with DVD cost*. Base case ICER $363. (B) Tornado diagram for 1-way sensitivity analysis: *without DVD cost*. Base case ICER $151. ER, emergency room; ICER, incremental cost-effectiveness ratio

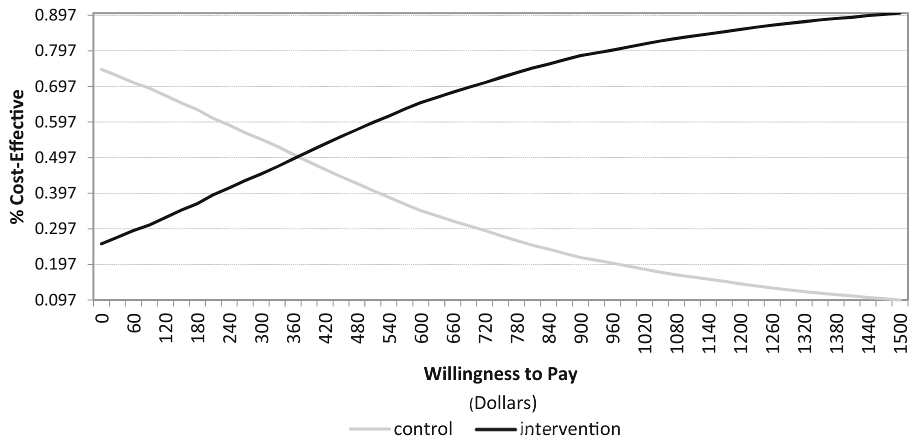

FIGURE 3 Cost-effectiveness (CE) acceptability curve

production of the DVD (a one-time expenditure) yielded a per participant cost of $393 and an ICER of $72 per BMI percentile point decrease. This level of investment appears modest, given the severity of adverse health outcomes related to childhood obesity. As this is among the first studies, of which we are aware, to provide a formal assessment of cost-effectiveness for the treatment of childhood obesity delivered mainly via primary care practice visits for this age group, a direct comparison with equivalent approaches is not possible.

However, there is a growing body of literature regarding costs for obesity interventions in pediatric primary care and for obesity treatment interventions in other clinical settings that may offer a sense of the spectrum of cost-effectiveness estimates. For example, a 2014 analysis of a primary care intervention consisting of MI delivered via four in-person and three telephone visits by pediatric nurse practitioners significantly decreased television viewing and unhealthy eating practices among children 2 to 6 years old [23]. However, the intervention did not achieve a significant change in BMI. Costs for children in the intervention group were found to be $296 per child and costs for children in the usual care group of the study were $72, yielding an incremental cost of $224 for the intervention with no significant change in BMI [23]. This suggests a potentially promising approach at modest cost, though in the absence of a statistically significant decrease in BMI, a cost-effectiveness analysis was not possible. A more intensive intervention, such as the BMI^2 approach reported here, may be needed to affect obesity in clinically and statistically significant ways [24].

In contrast, a 6-month family-based intervention for 8- to 12-year-olds led to a significant decrease in the severity of excess weight (measured in "percent BMI over the 50th percentile") at 12-month follow-up, with reported costs of $1,608 ($934 payer costs + $675 participant costs) per family and a child cost-effectiveness ratio of $232 per "percent over BMI" (calculated by comparing the participant's BMI with the BMI at the 50th BMI percentile for child age and gender) [25]. Comparisons between the outcomes of this 6-month study and BMI^2 are difficult to make, as it was a multidisciplinary intervention not offered in the primary care setting, and the measurement assessed was percent BMI over the 50th percentile at 12-month follow-up as opposed to change in BMI percentile at 2-year follow-up in our study. Similarly, percent over BMI was the measure used in a 2017 family-based intervention for 2- to 5-year-olds with obesity/overweight and their parents, delivered via 17 group sessions in primary care offices over the course of 2 years [26]. It showed an ICER compared with the control group of $129 for a 1% decrease in percent over BMI at 24-month follow-up [26]. Although percent over BMI is not directly comparable to the measures used in the current study, it does provide an indication of the ICER of other pediatric obesity interventions.

Although bariatric surgery is not a clinically appropriate treatment option for most patients in the age group included in the BMI^2 study, the costs of bariatric surgery warrant mentioning as patients who go on to become adolescents or adults with severe obesity may be considered candidates for invasive interventions such as surgery. The two most common procedures among adolescents, the Roux-en-Y gastric bypass and the sleeve gastrectomy, have a mean surgical cost of $27,001 ($17,234-$37,810) and $25,534 ($14,360-$37,691) per patient, respectively, not including other health or societal costs or the additional costs associated with complications [27]. One study of bariatric surgery costs reported average per patient costs of $28,260 and an average decrease in BMI of 13.2 BMI units, yielding surgical intervention costs of $2,141 per BMI unit (kilograms per meters squared) reduced [28]. However, without costs per BMI percentile unit change, direct comparisons are not possible with our findings.

In light of the broad range of possible approaches to obesity prevention and treatment, the consideration of costs in a wider context is necessary. To explore the cost-effectiveness of obesity interventions more broadly (including clinical, school-based, early childhood, community, and policy efforts), Gortmaker et al initiated the Childhood Obesity Intervention Cost-Effectiveness Study (CHOICES) [29,30]. This work illustrates how cost-effectiveness analyses may be used to understand the practical impact on population focused interests at the national level. For example, a microsimulation model of a national implementation of the Study of Technology to Accelerate Research (STAR) trial was performed. This trial using electronic health record decision support tools for primary care providers with self-guided behavior change support for parents of 6- to 12-year-olds with obesity resulted in a smaller increase in BMI over time among the intervention group compared with usual care patients [31]. The simulation projected the potential effects of the STAR intervention, if used by all PCPs with electronic health records in the United States over the course of 10 years, and estimated costs of $255 per BMI unit reduced [32]. In another CHOICES study, lower costs were projected for large-scale public policy efforts such as an excise tax on sugar-sweetened beverages, which has an estimated cost of $3.00 per BMI unit reduction [33]. Although direct comparisons with our findings are not possible because of different measures of impact on BMI, these interventions do provide a helpful context for understanding the similarly modest cost-effectiveness ratio that we found.

The cost for interventions to treat obesity among adults may also be helpful when considering our results. In a meta-analysis of commercial weight loss strategies, Finkelstein and Kruger assessed the cost-effectiveness of two lifestyle programs (Weight Watchers and Vtrim), one meal replacement program (Jenny Craig), and three medications (phentermine/topiramate, lorcaserin, and orlistat) [34]. They found the most favorable ICER was for Weight Watchers, with a mean cost per kilogram of weight loss of $155 (95% CI: $110-$218) relative to a low-cost control intervention. The least favorable intervention, among those assessed, was orlistat, with a mean cost per kilogram of weight loss of $546 (95% CI: $390-$736) [34].

Of note, our findings indicate a decrease in health care visits for children in the intervention group. This finding may be attributable to parents' questions being answered during the study-related visits, which would obviate the need for additional visits to discuss other health concerns. Alternatively, it is possible that frequent contact with a health care provider offers some reassurance and supports the worried well, thereby decreasing additional health care use. Exploring this issue fully was beyond the scope of the study, and further research is warranted to examine this question and to elucidate the mechanisms by which changes in visit frequency may be related to an intervention such as BMI^2. In the longer term, we hypothesize that interventions like the one studied may improve lifestyle habits, leading to a lower BMI percentile and better health status with an associated decreased need for health care services [35].

Our findings must be considered in light of certain study limitations. It is possible that the value of a change in BMI percentile may differ based on the patient's initial BMI percentile. Our ability to explore this question in the current study was limited by our sample size. In addition, participant dropout may not have been at random and could have led to a smaller denominator and higher ICER if those with less favorable changes in BMI were more likely to leave the study. Missing data were not imputed and were as high as 15% at year 1 for dining costs and out-of-pocket prescription costs. Participant costs were not objectively obtained but were from self-report at baseline, and the end of year 1 and year 2, which may have led to recall errors and may have impacted the accuracy of our estimates, including the accuracy of parental report of emergency department visits and medication use. However, we are unaware of any literature that would lead us to expect a systematic bias in parent reporting of these events and costs that would differ by intervention versus control groups. An additional limitation is that the number of family members was not collected at any time point and that the change in cost for food was collected at the family level. For families with more than one child, or with shifting family structures and dietary preferences over time unrelated to the intervention, estimates reported here may not reflect the incremental cost change attributable to the specific child enrolled. However, this should affect both the control and intervention arms similarly, which may mitigate this concern. Furthermore, in the absence of data regarding parental occupations, we used the Bureau of Labor Statistics "all-occupations" data; higher or lower wages for parents may have affected estimated costs and the ICER in ways that are not possible to predict. Finally, this study was conducted at PROS offices, which are well suited to conducting such interventions, and findings may differ in other practice settings.

Although we attempted to oversample among minority families, our sample size did not allow us to conduct analyses to determine whether the ICER differed by socioeconomic status, race, gender, or ethnicity. This remains a priority we plan to address in future studies. As it is possible that a population with greater diversity may have a greater sensitivity to the costs associated with participation, efforts may be needed to further minimize the costs borne by families. Although not large enough to impact the ICER of this study in a substantial way, grocery costs did increase among the intervention group. Although we did not ask families about reasons for change in their food costs, the cost of healthy foods is an oft-cited barrier to making healthy changes [36,37]. In addition, parents frequently express concern about children not eating fresh fruits and vegetables, which can lead to these costly foods being wasted [38]. In order to increase the uptake of this intervention, it may be helpful to counsel parents on economical approaches to healthy food options.

In summary, our findings offer an assessment of the costs associated with an effective MI intervention for treating pediatric obesity in the primary care setting and they may present a benchmark on which future analyses could be assessed. Educating PCPs and RDs to deliver MI-based interventions to address childhood obesity in primary care is effective and is associated with modest costs in the context of primary care-based weight management interventions for children. Further research is warranted to examine whether MI training for PCPs (and possibly medical students and residents) offers a longer-term opportunity for a cost-effective impact on obesity, as the durability of MI training may continue to favorably affect children's BMI trajectories over time and may also be amortized over an increasing number of children in a PCP's practice who develop obesity. Indeed, broadly disseminating the MI training materials may be a means of helping PCPs adopt approaches similar to those used in BMI^2, which, without the curriculum development costs, offer the potential of an improved ICER. Moreover, in light of improvements in technology and the widespread use of videoconferencing platforms implemented since the BMI^2 trial was conducted, it is possible that training costs could be much lower for future iterations of similar interventions.O

AUTHOR CONTRIBUTIONS

Susan J. Woolford participated in conceptualizing and designing the study. She drafted the initial manuscript and reviewed and revised the manuscript. Kenneth Resnicow participated in conceptualizing and designing the study. He participated in conducting the analyses and reviewed and revised the manuscript. Matthew M. Davis participated in conceptualizing and designing the study. He participated in conducting the analyses and reviewed and revised the manuscript. Lauren P. Nichols made a substantial contribution to the interpretation of the data, drafting the article, and providing the final approval. Richard C. Wasserman participated in conceptualizing and designing the study and reviewed and revised the manuscript. Donna Harris participated in conceptualizing and designing the study and reviewed and revised the manuscript. Achamyeleh Gebremariam made a substantial contribution to the analysis and interpretation of the data and contributed to reviewing and revising the manuscript. Laura Shone made substantial contributions to revising the study and reviewing and revising the manuscript. Alexander Fiks made substantial contributions to revising the study and reviewing and revising the manuscript. Tammy Chang made a substantial contribution to the design of the study, drafting the article and also providing the final approval. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors declared no conflict of interest.

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