Supplementing a widely available weight loss program with gamified inhibitory control training: A randomized pilot study

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Abstract

Background: Increasing evidence suggests that targeting self-regulatory processes may improve obesity treatment outcomes. Incorporating gamification principles in inhibitory control training may promote sustained training adherence and resulting benefits. This pilot study evaluated the preliminary efficacy of supplementing an evidence-based weight management program (WW) with sustained gamified inhibitory control training (PolyRules!) on change in Body Mass Index (BMI) among adults with overweight/obesity.

Methods: 30 adults with overweight/obesity (M age 49.9 ± 12.4, 86.7% female; 23.3% Hispanic, mean BMI 35.3 ± 6.3) were randomly assigned to receive WW with or without PolyRules! for 12 weeks. The primary outcome was change in BMI from baseline to post-intervention across study arms. Implementation and process indicators were captured to inform larger trials.

Results: Average change in BMI was −0.9 in the WW arm and −1.2 in the WW + PolyRules! arm (Cohen's d = 0.26). In the WW + PolyRules! arm, increased training was associated with greater decreases in BMI (r = −0.506, p = 0.0454). WW + PolyRules! participants completed an average of 60.4% sessions and reported positive experiences. There was no difference in frequency of food (d = −0.02) and weight tracking (d = −0.19) between arms.

Conclusions: Studies in larger samples should evaluate training-related effects on weight. Supplementing WW with gamified inhibitory training appears feasible, with no detrimental effect on engagement.

Keywords

impulse regulation, inhibitory control, obesity
1 | INTRODUCTION

In recent years, there has been an increased interest in understanding how cognitive and behavioral processes involved in inhibitory control may help explain heterogeneity in obesity treatment outcomes. Inhibitory control describes the ability to actively inhibit or delay a dominant response to control one’s attention and/or goal-oriented behavior, thereby withholding an automatic or prepotent response. Studies have found relationships between deficits in executive functioning and obesity, and there is evidence that poor inhibitory control may be associated with unhealthy eating, unsuccessful dieting, obesity and weight gain. These findings lead to the puzzling question of whether impulse control training confers benefits in the context of weight management.

Initial findings suggest that inhibitory control training may increase self-regulation in the context of health behaviors. Interventions based on the Go/No-Go task, a methodology for studying and training inhibitory control by challenging individuals to withhold dominant responses, have been shown to improve short-term eating regulation and produce modest weight-loss. However, the transfer of inhibitory control training gains have been a source of skepticism. These controversies may stem from previous studies’ key limitations such as limited dosage and training duration (e.g., <10 training sessions over 2 weeks), exposure to a small set of stimuli, and lack of tailoring to participants’ proficiency as the training progresses. The efficacy of these interventions in terms of producing ecologically-valid improvements is also unclear. To address the rigor of previous research, the Brain Game Center team has developed a novel inhibitory control training game (PolyRules!©), which incorporates stimuli and task structures previously applied in visual perceptual learning and working memory training. PolyRules! adjusts to users’ inhibitory control proficiency and incorporates gamification principles to sustain training frequency, duration, and promote adherence. Research indicates that gamification, if applied properly, may lead to increased enjoyment and greater training adherence and benefits.

The present study examined the preliminary efficacy of supplementing a weight-loss program (WW, formerly Weight Watchers©) with gamified inhibitory control training (PolyRules!) on Body Mass Index (BMI) change among adults with overweight or obesity. Implementation and process indicators (participants’ enrollment and attrition, adherence to and experience with WW components and inhibitory control training) were also captured to inform a larger trial, and to evaluate whether the addition of sustained inhibitory control training decreased engagement in WW components (daily dietary monitoring and weekly weigh-ins). The study team hypothesized that participants randomized to complete both WW and PolyRules! would report a greater change in BMI than participants randomized to WW alone. Further, it was hypothesized that combining WW and PolyRules! would not be unduly burdensome for participants.

2 | METHODS

2.1 | Study design

This study was a pilot, two-arm, randomized control trial comparing WW alone to WW with gamified inhibitory control training on change in BMI between baseline and post-intervention. Participants were block randomized with replacement by study staff to ensure that the two arms had similar demographic characteristics.

2.2 | Setting and participants

This study was conducted at Cedars-Sinai Medical Center in Los Angeles, California from March 2021 to July 2021. Individuals with overweight or obesity were recruited using electronic flyers posted on Cedars-Sinai’s internal hospital website and distributed by medical providers. Participants were eligible for the study if they were age 18 years or older and had a BMI > 25 kg/m². Participants were excluded if they were currently enrolled in another weight loss intervention, scheduled to undergo bariatric surgery, were pregnant or suffering from severe cognitive delays or visual/hearing impairments interfering with their ability to complete the inhibitory control training. All study procedures were approved by the Institutional Review Board at Cedars-Sinai Medical Center.

2.3 | Procedure

Due to COVID-19 restrictions, all research procedures were conducted and facilitated remotely by study staff. Interested individuals were screened over the phone to determine if they met the eligibility criteria. Interested and eligible individuals were asked to provide written consent through DocuSign. After providing written consent, participants were randomized by study staff to one of two study arms (WW only or WW + PolyRules!) using a previously generated randomization scheme. If a participant prematurely withdrew from the study, another participant was recruited to maintain the final analytic sample of 30. The new participants were not automatically assigned to the same condition, but rather randomized based on the original randomization scheme.

Participants who did not have a personal iPad were provided with one for the duration of the study to standardize access to the WW program and the PolyRules! game. At baseline, participants completed a demographic and medical history questionnaire. Participants also completed a cognitive battery pre- and post-intervention, and interactions with the WW program (daily food intake and weekly weight) and PolyRules! (training frequency) were continuously recorded to monitor engagement.
2.4 Interventions

Weight Watchers (WW). All participants were provided access to the digital WW program for 12 weeks. WW is a structured behavioral weight management program focusing on diet, physical activity, mindset, and sleep. The dietary approach is based on creating an energy deficit diet to produce weight loss while also being attentive to the quality of the calories. Specifically, the WW program assigns SmartPoints values to foods based on calories, sugar, saturated fat and protein. In addition, particular foods are assigned a points value of zero (0) to encourage a healthier eating pattern (e.g., fruits, vegetables). Upon sign-up, an individualized SmartPoints budget consisting of a daily SmartPoints target and weekly SmartPoints allowance is calculated based on height, weight, age and sex. The fitness component assigns FitPoints values to physical activities based on the type, duration, intensity and the participant’s body weight. Participants are instructed to log their food and beverage consumption daily and their weight weekly. WW does not require participants to track ZeroPoint foods. This decision is based on research indicating that tracking ZeroPoint foods increases burden without conferring additional benefits to weight loss. Although WW instructs participants to log their daily physical activity and permits syncing with smartwatches or similar devices, this data was not extracted in the present analysis because the food-specific inhibitory control training tested in this study was hypothesized to operate on self-regulatory processes most relevant to food intake. WW is the most studied and used commercial weight-management intervention, and the #1 doctor recommended program based on a 2019 survey by Kantar Health of 500 doctors. Both the in-person and digital WW program have helped users achieve clinically significant weight loss of 5% initial body weight.

WWW + inhibitory control training (PolyRules!). In addition to WW, participants randomized to the gamified inhibitory control training arm were instructed to play PolyRules. (Play experience illustrated in Figure 1). PolyRules! is an inhibitory control training application designed by the authors that combines elements of the Go/No-Go paradigm and rule switching tasks to train different aspects of cognitive functioning, including inhibitory control, attention and memory. For the present pilot study, neutral stimuli were supplemented with food-stimuli that participants were asked to respond and withhold responses to. Impulse control was conceptualized as a multifaceted construct in which controlling impulses occurs in a variety of contexts and involves food-related choices encountered in daily life (i.e., oatmeal vs. donut).

PolyRules! combines elements of the Go/No-Go and rule switching tasks. Participants are required to sort polygons based on features (shape, color, texture, size) when presented with healthy food or beverage options (Figure 1, top), and to inhibit sorting responses when presented with less healthy options (Figure 1, bottom). Rule-switching is introduced to add complexity to inhibitory control and prevent development of automatic sorting unrelated to inhibitory processes. Specifically, participants must inhibit the rule used in the previous task set and change the focus of their attention to a new sorting and/or inhibitory rule. A key attribute of the training is that the difficulty of the sorting and switching rules progressively increases based on participants’ abilities over the course of training. For example, in the early stages, the sorting rule involves simple matching of shape based on color or shape. As difficulty increases, the complexity of the sorting rules increases in combining features (e.g., color + size) and/or in switching between sorting correctly and incorrectly. Over 500 food and beverage stimuli are permuted across levels to simulate real-life decision-making (e.g., fruits vs. energy-dense snacks; healthy vs. less healthy drive-through options; grilled vs. fried foods). Food and beverage stimuli are presented in different combinations and ratios across blocks and levels to further increase the variety of stimuli and relative choices.

The duration of the training intervention was 12 weeks, and participants were instructed to complete five sessions per week. Each session was approximately 30 min in duration and consisted of 20 levels, with food and beverage stimuli presented in different combinations and ratios across blocks and levels to further increase the variety of stimuli and relative choices. All interactions with the app were saved on a remote server to monitor training frequency and saved data for variables of interest (reaction times, accuracy scores...etc.).
2.5 Measures

Body Mass Index (BMI). At baseline, participants self-reported their height in inches and weight in pounds and were told to continue reporting weight weekly throughout the study period as part of the WW program. Participants received weekly reminders to enter their weight in the WW app. Height was converted from inches to meters and weight was converted from pounds to kilograms to calculate BMI at baseline and post-intervention. Change in BMI was calculated by subtracting participants BMI post-intervention from their baseline BMI.

Cognitive functioning. At baseline and post-intervention, participants completed a cognitive battery on the Recollect the Study app. Recollect is a validated cognitive battery with computerized versions of cancellation and countermanding tasks to assess attention and inhibitory control and N-Back, Corsi Blocks and Letter-Number tasks to assess working memory. Study staff remotely assisted participants in accessing the Recollect app on the pre-loaded study iPad or in downloading the app on their personal iPad. The cognitive assessment lasted approximately 60 min at each time point.

Implementation and process indicators. Quantitative and qualitative implementation indicators were collected to inform the design of a future larger trial. Quantitative indicators included (1) reach and enrollment (enrolled participants/screened participants); (2) adherence to the study protocols (completion of study assessments), WW components (number of days dietary intake was tracked/total number of days dietary intake could be tracked; number of weigh-ins/total number of weekly weigh-ins) and PolyRules! training (trainings completed/number of trainings prescribed); and (3) attrition (participants who prematurely withdrew from the study/total enrolled participants). Participants were considered to have withdrawn from the study if, at any time over the course of the study, they expressed that they did not want to continue the intervention and/or complete the remaining assessments.

Qualitative indicators were assessed through a semi-structured interview with all participants at the end of the 3-month intervention. These interviews were conducted using Zoom or MS Teams, audio-recorded and transcribed using a non-verbatim approach. Interviews were analyzed using focused coding and yielded themes of motivation, facilitators and barriers of adherence, and participant satisfaction.

2.6 Data analysis

All statistical analyses were performed using SPSS 24 and SAS version 9.4 (SPSS Inc., Chicago, IL; SAS Institute Inc., Cary, NC). An a priori sample size calculation was not conducted due to the feasibility nature of this pilot study. Descriptive statistics including frequencies, percentages, means and standard deviations were used to characterize the sample. Cohen’s d effect sizes were calculated when appropriate. Differences between baseline and post-intervention continuous measures were tested using the paired t-test or Wilcoxon signed-rank test and differences between intervention arms were assessed using an independent sample t-test or Wilcoxon rank sum test, as appropriate. Spearman correlations were calculated to examine associations between the magnitude of change in BMI and adherence to WW (dietary intake tracking, weigh-ins) and PolyRules! components (trainings completed). Participants who withdrew from the study were replaced to maintain the final analytic sample of 30 participants. All participants, regardless of whether they completed all assessment timepoints, were included in the analyses. Given that this was a pilot trial, outcomes were interpreted for potential clinical significance based on the direction and magnitude of numerical differences.

3 RESULTS

The CONSORT diagram is illustrated in Figure 2. Of the 119 individuals who contacted the study team, four ultimately declined to participate. Two of those individuals had enrolled in other weight management programs, and two were no longer interested in participating in the study. Because the enrollment was capped at 30 participants, 81 individuals had to be waitlisted for future studies. Due to few exclusionary criteria, all interested individuals who were screened to participate in the study were eligible to participate.

Among participants who were consented in the study, four prematurely withdrew before treatment. Three of the participants who withdrew were randomized to the WW + PolyRules! arm, and one participant was randomized to the WW only arm. Two participants withdrew because they felt they could not commit to the study (WW + PolyRules!), while another participant withdrew because of the assigned study arm (WW only). One individual never actively withdrew from the study but failed to initiate the intervention and complete the study assessments (WW + PolyRules!). Table 1 summarizes the demographics of the final analytic sample.

3.1 BMI change and correlates

Regardless of intervention arm, participants’ average BMI was significantly lower after completing the intervention (M = 34.5, SD = 6.2) than at baseline (M = 35.3, SD = 6.2, t(28) = 4.96, p < 0.001). Individuals’ BMI changes across study arms are illustrated in Figure 3. Change in BMI was −0.9 (SD = 1.1; 2.5% weight loss) in the WW arm, and −1.2 (SD = 1.2; 3.4% weight loss) in the WW + PolyRules! arm (d = 0.26). There was no difference in the cognitive battery scores from baseline to post-intervention across intervention arms.

More frequent food tracking was associated with a greater decrease in BMI (r = −0.385, p = 0.0394) in both study arms. In the WW + PolyRules! arm, the number of inhibitory control trainings completed was associated with greater decreases in BMI (r = −0.506, p = 0.0454).
3.2 | Implementation and process indicators

Most participants (85.29%) completed all study assessments and procedures. On average, participants tracked their daily food intake on 65.6% of the possible days, and their weekly weight on 78.6% of the possible weeks. There was no difference in dietary ($p = 0.97$) and weight ($p = 0.74$) monitoring across study arms. WW participants tracked their food 66.0% ± 33.6% of the time, and WW + PolyRules! participants tracked their food 65.3% ± 33.3% of the time. Similarly, WW participants completed 80.8% ± 27.2% of the weekly weigh-ins, while those in the WW + PolyRules! arm tracked their weight 77.0% ± 30.1% of the time. Participants in the WW + PolyRules! arm completed 60.4% ± 32.4% of the training sessions.

In the post-intervention interviews, several themes were identified, with the primary being a positive experience with the study procedures and the inhibitory control training. The colors, shapes, and sounds of PolyRules! were described by participants as enjoyable, fun, and easy to play. A secondary theme identified was the perceived benefits of inhibitory control training. Participants felt that the inhibitory control training helped with weight loss, with one reporting it "helped me become more aware of unhealthy foods"). Other frequently cited perceived benefits from using PolyRules! were in terms of improved attention to details, concentration, focus, and memory. In the third and final theme, app dislikes and suggested improvements, participants described some of the features of the app that they disapproved of and felt could be improved. Some participants noted the lack of variety in food pictures, while others...
TABLE 1 Participants’ demographic characteristics (N = 30)

| Participants’ characteristics and baseline measures | Mean ± SD (Range) or N (%) |
|-----------------------------------------------------|--------------------------|
| Age (Years)                                         | 49.9 ± 12.4 (26–76)      |
| Female                                              | 26 (86.7%)               |
| Baseline body Mass Index (BMI)                      | 35.3 ± 6.2               |
| Hispanic                                            | 7 (23.3%)                |
| Race                                                 |                          |
| White                                               | 23 (76.7%)               |
| Black or African American                           | 5 (16.7%)                |
| Other                                               | 2 (6.7%)                 |
| Education                                           |                          |
| High School                                         | 1 (3.3%)                 |
| Technical/Vocational training                      | 2 (6.7%)                 |
| Associate degree                                    | 6 (20.0%)                |
| Bachelor’s degree                                   | 13 (43.3%)               |
| Post-graduate degree                                | 8 (26.7%)                |
| Marital Status                                      |                          |
| Single                                              | 6 (20.0%)                |
| Married/Living with significant other               | 20 (66.7%)               |
| Separated/Divorced/Widowed                          | 4 (13.3%)                |
| Income                                              |                          |
| Less than $74,999                                   | 8 (26.7%)                |
| $75,000–$99,999                                     | 2 (6.7%)                 |
| More than $100,000                                  | 15 (50.0%)               |
| Refused to answer                                   | 5 (16.7%)                |

mentioned that the instructions were sometimes ambiguous. Others mentioned that the appearance and clarity of the food images could be improved.

4 | DISCUSSION

This pilot study examined the preliminary efficacy and overall feasibility of supplementing an evidence-based, widely available weight-management program with gamified inhibitory control training among adults with overweight or obesity. Although the intervention period was fairly short by weight management standards, 44% of WW + PolyRules! participants and 31% of WW alone participants lost >1.5 BMI points over the 3-month study. On average, participants assigned to the combined arm (−1.2 BMI points) lost slightly more weight than participants assigned to WW alone (−0.9 BMI points), but this difference did not reach statistical significance.

Importantly, the addition of daily impulse control training did not seem to unduly burden participants in decreasing their engagement with dietary and weight monitoring. The enthusiastic response to recruitment material was also encouraging, with 119 individuals who contacted the study team within 5 weeks. Only a few individuals prematurely withdrew from the study, and most enrolled participants completed all study procedures. Adherence to WW and PolyRules! was also high, suggesting that participants were able to carry out the remote interventions simultaneously.

Study strengths include the use of a widely available weight management intervention, and sustained (60 sessions over 12 weeks), adaptive, gamified inhibitory control training targeting core processes possibly involved in eating behaviors. Importantly, WW and PolyRules! components were delivered remotely. Although remote delivery is no longer scientifically novel, it greatly reduces
participants’ transportation burden, promotes behavior change in the
day-to-day environment and increases the scalability potential of this
work.46,47 These considerations are especially important in light of
the precipitated transformation in health care delivery due to the
COVID-19 pandemic.

Akin to other pilot studies, this work includes several limitations
related to the small and homogeneous sample of participants. In-
dividuals who took part in the study were highly educated, affluent
and 86.7% were women. The length of the intervention was also
fairly short by weight management program standards.

Another key limitation of this pilot study is the reliance on self-
reported anthropometric data. The financial resources and staffing
allocated to this study precluded purchasing of electronic scales or
scale drop off, especially considering the vast geographical area
(4753 square miles) where participants were recruited. Ultimately,
self-report was utilized in this pilot study to inform the refinement of
procedures for a larger study. Although potential biases were mini-
mized due to randomization, future studies using more rigorous
methods to capture objective anthropometric data are needed.

It is also important to acknowledge that participants randomized
to the WW only group were not assigned a control training condition.
Conceivably, structured/prescribed time allocation to a distracting
activity incompatible with eating may enhance weight management
efforts regardless of whether the activity targets inhibitory control.
This hypothesis is consistent with research on distraction and
inhibitory control.48 Structuring time to engage in alternate activities
may shift individuals’ focus away from eating and/or craving, espe-
cially if individuals engage in the alternate activity at a time when
they are more likely to eat.49

5 CONCLUSION

This was the first trial to examine the preliminary efficacy and
feasibility of supplementing a weight management intervention with
sustained gamified inhibitory control training. Overall, the study
procedures appear feasible, but limitations preclude conclusions in
terms of the clinical utility, generalizability, and sustainability of
these findings. The lessons learned in this pilot study will inform
the development of a larger trial rigorously testing the efficacy of impulse
control interventions in terms of producing ecologically valid
improvements and, importantly, who may benefit from inhibitory con-

CONTROL TRAINING.

AUTHOR CONTRIBUTIONS

Sarah-Jeanne Salvy and Aaron R. Seitz conceptualized and designed
the study. Sarah-Jeanne Salvy acquired funding and oversaw the
study implementation. Renette A. Cáceres and Qihan Yu conducted
data collection, wrote the first draft of the manuscript with critical
input from Sarah-Jeanne Salvy, Aaron R. Seitz, and Gary D. Foster,
and they developed all study-related materials and implemented
study procedures. Mark Philipp contributed to app design and
maintenance. Rebecca Tuckerman and Audrey Carrillo provided
guidance on cognitive measures and interpretation. Renette A.
Cáceres and Qihan Yu consulted with Marie Lauzon and Marcio A.
Diniz to conduct statistical analyses. All authors read and approved
the final manuscript.

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CONFLICT OF INTEREST

Gary D. Foster is the Chief Scientific Officer at WW International,
Inc., and is a shareholder. All other authors declare that they have no
competing interests to disclose.

CLINICAL TRIALS REGISTRATION, ETHICS APPROVAL
AND CONSENT TO PARTICIPATE

The protocol for this study has been approved by the Cedars-Sinai
Medical Center Institutional Review Board (STUDY00001164) and
is registered with ClinicalTrials.gov (NCT04747886). Participants
were asked to provide consent to participate in the study.

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