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Impact of an Adaptive Worksite Diabetes Prevention Trial on Health Action Process Approach Outcomes regarding Dietary Intake and Physical Activity

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Abstract

Weight loss, through a reduction in energy intake and increase in energy expenditure, can reduce diabetes risk in people with prediabetes. However, lifestyle change can be challenging even with positive intentions. The Health Action Process Approach (HAPA) theoretical framework bridges the intention-behavior gap by targeting planning behaviors and strengthening efficacious beliefs for behavioral change. In the current trial, an adaptive design was employed to examine differences in HAPA measures (i.e., planning and self-efficacy) regarding the target behaviors of dietary intake and physical activity (PA). Adults ≥ 21 years old with overweight or obesity and prediabetes (n = 185) received the standard Group Lifestyle Balance (GLB) intervention during the first month of treatment. Weight loss responders (lost > 2.5% of weight) at week five remained in GLB during weeks 5-16; slow responders (lost ≤ 2.5%) were stratified to the adaptive GLB Plus (GLB+) intervention during weeks 5-16. GLB+ augmented self-regulatory skills and practices consistent with HAPA. We conducted mixed model analyses with a group-by-time interaction for fixed effects at four months. GLB experienced greater improvement in behavioral intention for both diet and PA, planning behaviors (action and coping planning) for diet, and self-efficacy beliefs (action and maintenance self-efficacy) for PA compared to GLB+ (all ps < .0125). However, GLB+ also experienced statistically significant improvement in planning and self-efficacy and in energy intake and food group servings (all ps < .01). Whereas an adaptive intervention can be advantageous in improving HAPA measures and food choices, greater focus on increasing PA is needed. Additional research may help to determine effective PA strategies.

Keywords

lifestyle risk reduction, behavioral medicine, food intake, physical activity, weight loss

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The authors have no conflicts of interest to declare.

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Abstract

Weight loss, through a reduction in energy intake and increase in energy expenditure, can reduce diabetes risk in people with prediabetes. However, lifestyle change can be challenging even with positive intentions. The Health Action Process Approach (HAPA) theoretical framework bridges the intention-behavior gap by targeting planning behaviors and strengthening efficacious beliefs for behavioral change. In the current trial, an adaptive design was employed to examine differences in HAPA measures (i.e., planning and self-efficacy) regarding the target behaviors of dietary intake and physical activity (PA). Adults ≥ 21 years old with overweight or obesity and prediabetes (n = 185) received the standard Group Lifestyle Balance (GLB) intervention during the first month of treatment. Weight loss responders (lost > 2.5% of weight) at week five remained in GLB during weeks 5-16; slow responders (lost ≤ 2.5%) were stratified to the adaptive GLB Plus (GLB+) intervention during weeks 5-16. GLB+ augmented self-regulatory skills and practices consistent with HAPA. We conducted mixed model analyses with a group-by-time interaction for fixed effects at four months. GLB experienced greater improvement in behavioral intention for both diet and PA, planning behaviors (action and coping planning) for diet, and self-efficacy beliefs (action and maintenance self-efficacy) for PA compared to GLB+ (all *p*s < .0125). However, GLB+ also experienced statistically significant improvement in planning and self-efficacy and in energy intake and food group servings (all *p*s < .01). Whereas an adaptive intervention can be advantageous in improving HAPA measures and food choices, greater focus on increasing PA is needed. Additional research may help to determine effective PA strategies.

Key words: lifestyle risk reduction; behavioral medicine; food intake; physical activity; weight loss

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Introduction

Lifestyle interventions targeting dietary intake and physical activity (PA) are effective in reducing risk for type 2 diabetes in people with prediabetes. Notably, authorities with the Diabetes Prevention Program (DPP) found a 58% reduction in the incidence of type 2 diabetes following an intensive lifestyle intervention as compared with placebo (Knowler et al., 2002). An effective group-based adaptation of the DPP intervention, entitled Group Lifestyle Balance (GLB), was subsequently developed for prevention purposes (The DPP Research Group, 2002).

Fixed behavioral weight loss interventions, such as GLB, offer one treatment to all participants with varying levels of success (Unick et al., 2017). In contrast, adaptive interventions tailor treatment to individuals by modifying intervention dose, delivery mode, or content based on participant characteristics, needs, or response (Murphy et al., 2007). Adaptive interventions include at least one critical decision timepoint where an explicit decision rule is used to inform treatment assignment based on one or more tailoring variables. For example, an assessment conducted at intervention week five (i.e., decision timepoint) and weight loss status (i.e., tailoring variable) could be used to allocate slow responders to an adaptive intervention and early responders to a standard intervention (i.e., decision rule).

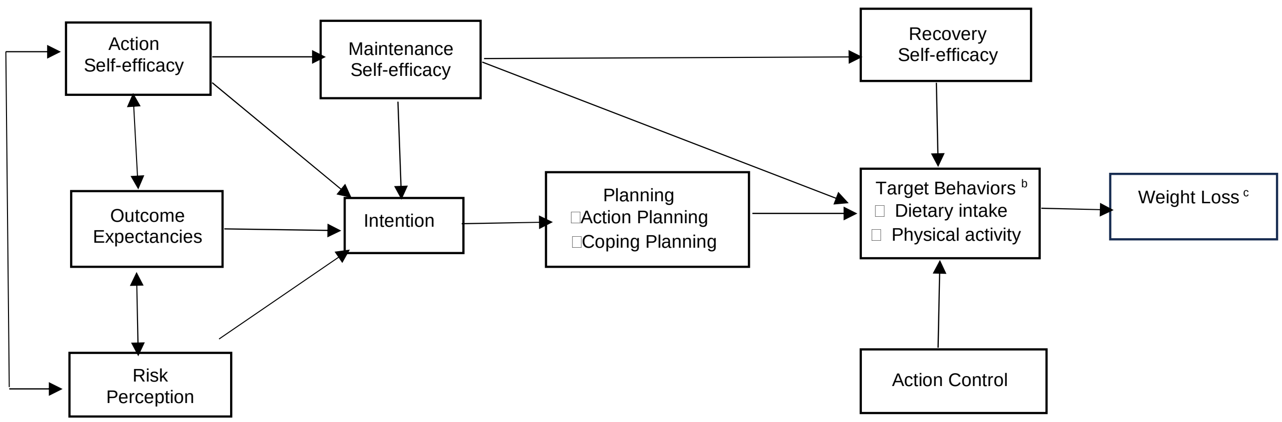
Adaptive interventions may be beneficial in weight management and diabetes prevention given the relationship between slow response and weight loss. Previous research demonstrates that participants who respond early during a weight loss intervention (e.g., the first month) experience prolonged success compared to slow responders (Unick et al., 2015; Unick et al., 2014; Carels et al., 2003; Miller et al., 2015). Thus, an adaptive intervention, in which slow responders are stratified to a tailored intervention could be more efficacious.

Furthermore, interventions grounded in theory leverage behavioral mechanisms to facilitate behavioral change (Collins et al., 2005; Glanz et al., 2010). Theoretical frameworks, such as the Health Action Process Approach (HAPA), focus on self-regulatory mechanisms, such as goal setting, to promote change (Schwarzer, 2008). The HAPA may be an effective framework for a goal-based intervention given the intervention focus on intention formation and goal pursuit.

In the current study, we used the HAPA framework to promote dietary and PA goals to reduce risk for type 2 diabetes. To replace a health compromising behavior with a health enhancing behavior, sufficient motivation is needed to initiate change via intention formation (Schwarzer, 2008). Three socio-cognitive factors (Figure 1) influence intention formation: risk perception, outcome expectancies, and action self-efficacy. Risk perception represents one's belief regarding susceptibility to possible health threats. Outcome expectancies reflect the consequences of engaging in a behavior, and action self-efficacy represents the capacity to perform the behavior. Sufficient levels of action self-efficacy operate in concert with risk perception and outcome expectancies to strengthen motivation for change.

Once an intention to change is established, planning is needed for success. The HAPA includes two types of planning: action and coping planning (Sniehotta et al., 2005). Action planning specifies the "what, when, where, and how" an intention will be implemented. Coping planning is the process of anticipating obstacles that might derail the intention and identifying strategies for minimizing obstacles. When an obstacle is encountered, coping planning serves as a cue-to-action to implement a premeditated plan. Furthermore, the HAPA postulates that distinct types of self-efficacy are needed to initiate and maintain a behavior. Maintenance self-efficacy (also called coping self-efficacy) represents the belief that one can initiate the target behavior and overcome obstacles encountered, whereas recovery self-efficacy represents the belief that one can recover from setbacks to enact and sustain the behavior. We added action control to the framework in this study to assess one's confidence in navigating common obstacles to goal attainment. Thus, planning, self-efficacy, and action control are key components of successful intention implementation.

Figure 1
The Health Action Process Approach theoretical framework adapted for adults with prediabetes [a]



Note.
[a] The model was adapted from Schwarzer, 2008.
[b] The current paper focuses on the target behaviors of dietary intake and physical activity, which can promote weight loss.
[c] The weight loss findings are reported in Miller et al., 2022

Current Research

In the current study, we designed an augmented intervention using the HAPA as a guiding framework in an adaptive trial to meet the needs of slow weight loss responders. The impact of this adaptive design in closing the gap between early and slow responders on weight loss are reported elsewhere (Miller et al., 2022). Because dietary intake and physical activity affect energy balance and weight loss, we present here the impact of the trial on these behavioral targets and determinants of those behaviors (i.e., HAPA measures) at four months. We hypothesized that participants in both treatment groups would report significant gains in the behavioral determinants and target behaviors.

Methods

Participant Eligibility and Recruitment

Worksites are a potentially viable avenue for diabetes prevention efforts given the time employees spend at the workplace, the shared worksite environment, and the interaction with and support from co-workers (Goetzel & Ozminkowski, 2008). Worksite interventions do not require additional time away from family or other outside-of-work commitments. Through worksite programs, employees can be engaged in a supportive community over an extended period of time, which allows people to cycle through the cognitive, emotional, and behavioral processes necessary to make lasting behavioral change. Finally, both the employer and employee have a personal stake in health and well-being. Improvement in health outcomes for even a small proportion of the workforce could translate into less absenteeism and cost savings (Baicker et al., 2010). Thus, worksites may provide an avenue for long-term support, and adaptive interventions could be implemented as a component of health promotion efforts.

Given the benefits of worksites, we implemented the intervention at a Midwestern university worksite. We recruited participants via campus emails, flyers, and advertisements on the university newswire. Eligibility criteria included being a ≥ 21-year-old employee with a body mass index ≥ 25 kg/m^2 (≥ 23 kg/m^2 for Asian individuals) and evidence of prediabetes via a fasting capillary glucose of 100-125 mg/dL or A1c of 5.7%-6.4% (American Diabetes Association Professional Practice Committee, 2024). Participants could not be diagnosed with diabetes, be pregnant or lactating, be taking glucose-lowering medication, be pursuing bariatric surgery, be enrolled in another weight loss program, or be planning to leave the university. Additional exclusion criteria were chosen to limit potentially confounding factors. These were: (1) responding positively to ≥ 1 response on the Physical Activity Readiness questionnaire, potentially indicating an inability to perform the recommended level of PA (Shephard, 1988); (2) scoring > 9 on the Personal Health Questionnaire-8, indicating the presence of depressive symptoms (Kroenke et al., 2010); or (3) scoring > 26 on the Binge Eating Scale, indicating the potential for binge eating, (Gormally et al., 1982).

Research Design

We implemented two lifestyle interventions, GLB and Group Lifestyle Balance Plus (GLB+), to promote behavioral change through the adoption of a lower energy diet and greater engagement in PA. The behavioral goals for both interventions were consistent with the original DPP and included to: consume < 25% energy from total fat and engage in ≥ 150-minutes/week of moderate-intensity PA (Knowler et al., 2002). The GLB intervention is described elsewhere (The DPP Research Group, 2002). Briefly, GLB addressed fundamental knowledge and skills in reducing energy and fat intake and increasing energy output and included strategies for reducing social and environmental challenges often encountered in maintaining lifestyle change.

The augmented GLB+ intervention incorporated self-regulatory skills including intention formation, goal setting, and planning addressed in the HAPA. Risk perception and outcome expectancies were addressed by explaining the relationship among lifestyle behaviors and diabetes and emphasizing the positive outcomes of a healthful lifestyle. Problem-solving skills included the creation of detailed action plans for intention implementation and goal pursuit, and coping plans were created for minimizing obstacles to change. Multiple routes to goal attainment were developed, and incremental goal setting was encouraged to enhance maintenance self-efficacy. Feedback occurred during weekly group discussions following goal striving. When setbacks occurred, we encouraged participants to use the situation as a learning opportunity (rather than failure) and adjust the goal to improve the likelihood of success, no matter how small, to strengthen recovery self-efficacy.

The intensive intervention phase consisted of 16 weekly, 60-minute, group sessions. All participants received the standard GLB intervention during the first month. Based on prior research (Miller et al., 2015), percent weight change was assessed at week five. Those who lost > 2.5% of body weight remained in the standard GLB intervention for the remaining 12 weeks. Participants who failed to lose > 2.5% of body weight at week five were stratified to GLB+ for the remaining 12 weeks. Initially, group sessions were delivered in-person. As a result of the SARS-CoV-2 pandemic, we implemented videoconferencing sessions in 2020 for intervention delivery. We delivered weekly group sessions synchronously via teleconferencing at the scheduled meeting times following onset of the pandemic. We assessed outcomes pre- and post-intervention during in-person data collection visits at the university using an approved safety protocol.

Participants were unaware of differences between the interventions. They were informed that a purpose of the study was to evaluate two versions of the program, but participants did not know how the two interventions differed from each other nor the criteria used for treatment stratification. The health coaches also were unaware of the content and membership differences between treatment groups.

Instruments and Measures

HAPA Instrument

Each HAPA component was assessed for program evaluation (Table 2). *Risk perception* was assessed using the previously validated Risk Perception Survey-Developing Diabetes (Walker et al., 2003). This instrument included five subscale scores (i.e., personal control, worry, optimistic bias, personal disease risk, comparative environmental risk) and a total score. The composite risk score, the mean of all items, was used for analyses. There were no known instruments available at trial initiation for assessing the HAPA components for dietary- and PA-related behaviors. Thus, items assessing other HAPA components were adapted from instruments used previously (Schwarzer, 2008; Schwarzer et al., 2011; Schwarzer & Renner, 2000; Scholz et al., 2008). *Outcome expectancies* assessed perceptions relating to personal consequences of healthy food choices (e.g., I will be less hungry) or engaging in PA (e.g., I will have more energy). *Action self-efficacy* assessed confidence in making dietary- or PA-related decisions (e.g., choosing low calorie foods as part of an eating routine; being physically active even when the weather is bad). *Action planning* assessed dietary planning and PA engagement (e.g., foods to eat when eating out; days of the week to be physically active). *Coping planning* assessed the ability to plan for anticipated obstacles (e.g., after a setback). *Maintenance self-efficacy* assessed confidence in one's ability to continue healthy dietary and PA behaviors in various situations (e.g., when receiving little support from others). *Recovery self-efficacy* assessed confidence in resuming healthy eating habits and PA following goal derailment (e.g., after an illness). One response, ranging from 0% (not at all confident) to 100% (extremely confident), assessed *behavioral intention* (i.e., to eat a low-fat diet most days of the week within the next month; to participate in PA at least five times/week for ≥ 30 minutes on each occasion). Because various obstacles are encountered when making food choices, we added *action control* to the study to assess one's confidence in navigating various obstacles (e.g., social events, watching television) during food selection (Sniehotta et al., 2005). Mean subscales for each HAPA variable were used for analyses.

Usual Dietary Intake

The self-administered Block 2014 food frequency questionnaire (FFQ) was administered to assess *usual dietary intake* in the preceding year (NutritionQuest, Berkeley, CA). The FFQ contains 127 food and beverage items. The participant indicated how frequently items were consumed (i.e., from never to daily) and the quantity consumed, using a portion size visual aid to assist with portion size estimation. The FFQ previously demonstrated adequate validity and reliability (Block et al., 1986; Block et al., 1994). Estimated energy intake, percent energy from fat, and the U.S. Department of Agriculture's food group servings were determined for analysis.

Minutes of Physical Activity

We also asked participants to wear a Fitbit Flex2 (San Francisco, CA) accelerometer on the non-dominant wrist for seven consecutive days preceding each data collection period to assess *minutes of PA*. All active days of PA, defined as > 1000 steps/day, were included in the analyses and intensity of PA was determined for all active days. Fitbit's proprietary algorithm for determining PA intensity consists of very, fairly, and lightly active minutes, which coincides with vigorous, moderate, and light metabolic equivalents (*Fitabase Data Dictionary*, 2021). Very and fairly-active minutes were summed for the week and compared to the study goal of obtaining ≥ 150 minutes/week of moderate-intensity PA.

Data Analysis

We compared participant demographic characteristics between groups using the Wilcoxon rank sum or Fisher's exact tests. Cronbach's coefficient alpha assessed internal consistency for each HAPA subscale. Linear mixed models with a group-by-time interaction term for the fixed effects were conducted to assess the between- and within-group change in outcomes. Change scores were represented by the (four months - baseline) calculation. Standardized residuals were used to remove outliers within the models. A p-value of < .0125 was used to indicate statistical significance to account for the Bonferroni correction of the four comparisons of between- and within-group changes. Because there were no major differences in the change in outcomes by intervention delivery method, all delivery formats were combined within treatment group for analyses. Linear mixed models with a delivery format-by-time interaction term for the fixed effects assessed the within-treatment group differences across intervention delivery formats (i.e., in-person, hybrid, or videoconference). We used the JMP Pro 16 statistical software package for analyses (Cary, NC, 2021).

Results

Table 1 reports participant characteristics from this university sample. We found no statistically significant differences between treatment groups at baseline apart from sex (p = .003). Cronbach's coefficient alpha, an indicator of internal consistency, for HAPA measures were acceptable (≥ 0.8) for all subscales except action self-efficacy for dietary intake (α = 0.6; Cronbach, 1951). Based on percent weight change at session five, 79 participants were stratified to GLB, and 106 participants were stratified to GLB+.

Comparison of Outcomes between Treatment Groups

Mean behavioral intention to consume a low-fat diet (F(1,312.3) = 8.91, p = .003; 95% CI [2.72, 13.25]) and mean action planning for dietary intake (F(1,349.7) = 10.56, p = .001; 95% CI [0.22, 0.90]) significantly differed by treatment group at baseline, with GLB+ reporting greater values (Table 2). Mean baseline grams of oil consumed also significantly differed between treatment groups (F(1,284.9) = 11.28, p < .001; 95% CI [2.29, 8.78]), with GLB consuming a greater quantity (Table 3). Only four participants in the sample met the goal of achieving < 25%

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Table 1
Baseline participant characteristics by treatment group

Characteristic	GLB [a] (n = 79)	GLB+ [b] (n = 106)	p-value
	Mean (± SD) [c]		
Age (years)	52.76 (±10.0)	51.19 (±10.19)	.24
	n (%) [d]		
Race			.13
American Indian or Alaska Native	0	1 (0.94)	
Asian	5 (6.33)	6 (5.66)	
Black	5 (6.33)	17 (16.04)	
White	69 (87.34)	79 (74.53)	
More than one race	0	1 (0.94)	
Unknown or not reported	0	2 (1.89)	
Ethnicity			.35
Latinx	1 (1.27)	3 (2.83)	
Not Latinx	78 (98.73)	100 (94.34)	
Unknown or not reported	0	3 (2.83)	
Sex			.003
Female	49 (62.03)	87 (82.08)	
Occupation			.32
Professional	42 (55.26)	67 (65.05)	
Clinical	11 (14.47)	10 (9.71)	
Clerical	14 (18.42)	20 (19.42)	
Technical/ Technology	7 (9.21)	6 (5.83)	
Other	2 (2.63)	0	
Household income			.63
< $49,999	6 (7.89)	12 (11.76)	
$50,000 to $69,999	13 (17.11)	15 (14.71)	
$70,000 to $99,999	18 (23.68)	17 (16.67)	
$100,000 to $149,999	23 (30.26)	30 (29.41)	
≥ $150,000	16 (21.05)	28 (27.45)	
Highest level of education			.47
High school diploma/ GED/ vocational/ trade	5 (6.33)	3 (2.86)	
Some college or bachelor’s degree	38 (48.10)	49 (46.67)	
Graduate training/ degree	36 (45.57)	53 (50.48)	

Note.
[a] Group Lifestyle Balance (GLB) standard intervention group
[b] Group Lifestyle Balance Plus (GLB+) augmented intervention group
[c] Wilcoxon Rank Sum test of between-group difference of means
[d] Fischer’s Exact Test of between-group differences for a categorical response

of energy from fat at four months. Statistically significant group-by-time interactions were observed for behavioral intention to consume a low-fat diet ($F(1,175.5) = 17.48$, $p < .001$; 95% CI [3.32, 9.26]), action planning ($F(1,178.1) = 12.39$, $p < .001$; 95% CI [0.17, 0.60]), and coping planning ($F(1,180.9) = 6.58$, $p = .011$; 95% CI [0.07, 0.54]) for dietary intake at four months. Also, we found statistically significant group-by-time interactions for behavioral intention to engage in PA ($F(1,176.3) = 6.44$, $p = .0120$; 95% CI [0.99, 7.91]), action self-efficacy ($F(1,181) = 14.68$, $p < .001$; 95% CI [0.13, 0.42]), and maintenance self-efficacy ($F(1,181)=13.19$, $p < .001$; 95% CI [0.18, 0.60]) for PA at four months (Table 2). GLB participants reported greater changes in these measures compared to GLB+ participants. We found no statistically significant group-by-time interactions for the composite risk score for diabetes, dietary outcomes, or minutes of moderate-intensity PA. There was a statistically significant between-group difference in the proportion of participants who met the goal of 150 minutes/week of moderate-intensity PA with 69.4% and 48.4% in GLB and GLB+, respectively ($p = .01$) meeting the goal at four months.

Comparison of Outcomes within Treatment Group

Because both groups received treatment, we examined the impact of each intervention on outcomes from baseline to four months. We found statistically significant main effects of time (all *p*s < .01) within both groups for all HAPA measures except for behavioral intention to engage in PA for GLB+ ($p = .06$; Table 2). We also found statistically significant main effects of time in GLB and GLB+ for energy intake and intake of protein, dairy, grain, solid fat, oils, and added sugars (all *p*s < .01; Table 3). Furthermore, there was a statistically significant main effect of time for the change in moderate-intensity PA in GLB ($p < .001$; Table 3). There were no statistically significant changes within-group for the composite diabetes risk score.

Comparison of Outcomes by Intervention Delivery Method

There were no statistically significant differences in measures between intervention delivery formats (i.e., in-person, hybrid, or videoconference) within treatment group at baseline. Similarly, there were no significant differences in the change in measures by delivery format except for dietary outcome expectancies in GLB+. We did not find that participants who attended in-person sessions reported a significant increase in these outcome expectancies (data not shown).

Discussion

This is one of the first studies to utilize an adaptive intervention and assess change in HAPA, dietary, and PA outcomes between early and slow responders during a behavioral intervention for diabetes prevention. At four months, we found significantly greater changes for the GLB group in behavioral intention to consume a low-fat diet and engage in PA, action and maintenance self-efficacy for PA, and action and coping planning for dietary intake compared to the GLB+ group. By design, GLB+ participants experienced slower initial weight loss (Miller et al., 2022). However, despite a slower response, GLB+ participants also exhibited statistically significant improvement in the HAPA measures (excluding behavioral intention for PA), comparable to that of GLB. Participants in both treatment groups also experienced significant reductions in total energy intake and food group servings, excluding servings

Table 2

Least squares mean (±SE) for risk perception and HAPA measures by treatment group at baseline and change at four months

Risk Perception for Type 2 Diabetes							
		Baseline			**Change at four months**		
Measure	**Cronbach's α**	**GLB [a] (n = 79)**	**GLB+ [b] (n = 106)**	***p*-value [c]**	**GLB (n = 79)**	**GLB+ (n = 106)**	***p*-value [d]**
Composite Risk Score [e] (32 items)	0.84	2.35 (±0.04)	2.34 (±0.03)	.845	0.05 (±0.03)	0.01 (±0.02)	.337
HAPA Measures regarding Dietary Intake							
		Baseline			**Change at four months**		
Measure [f]	**Cronbach's α**	**GLB (n = 79)**	**GLB+ (n = 105)**	***p*-value**	**GLB (n = 79)**	**GLB+ (n = 105)**	***p*-value**
Outcome Expectancies (4 items)	0.78	5.75 (±0.09)	5.84 (±0.08)	.446	0.34 (±0.09)***	0.33 (±0.08)***	.952
Action Self-efficacy (4 items)	0.55	4.64 (±0.11)	4.91 (±0.10)	.074	0.88 (±0.13)***	0.50 (±0.11)***	.024
Action Planning (5 items)	0.91	4.31 (±0.13)	4.87 (±0.11)	.001	1.60 (±0.17)***	0.83 (±0.14)***	< .001
Coping Planning (5 items)	0.95	3.15 (±0.14)	3.50 (±0.12)	.063	2.11 (±0.18)***	1.50 (±0.15)***	.011
Maintenance Self-efficacy (5 items)	0.88	4.89 (±0.11)	4.94 (±0.09)	.687	0.96 (±0.12)***	0.71 (±0.10)***	.109
Recovery Self-efficacy (4 items)	0.90	4.93 (±0.11)	5.02 (±0.10)	.548	1.02 (±0.12)***	0.84 (±0.11)***	.284
Behavioral Intention [g] (1 item)	-	60.0 (±2.02)	67.98 (±1.75)	.003	20.85 (±2.29)***	8.27 (±1.96)***	< .001
Action Control (9 items)	0.84	4.36 (±0.11)	4.22 (±0.10)	.340	0.52 (±0.13)***	0.43 (±0.11)***	.609

HAPA Measures regarding Physical Activity and Weight-related Behaviors							
		Baseline			**Change at four months**		
Measure [f]	**Cronbach's α**	**GLB (n = 78)**	**GLB+ (n = 105)**	***p*-value**	**GLB (n = 78)**	**GLB+ (n = 105)**	***p*-value**
Outcome Expectancies (13 items)	0.80	5.77 (±0.06)	5.85 (±0.05)	.324	0.14 (±0.05)**	0.18 (±0.04)***	.574
Action Self-efficacy (10 items)	0.81	4.20 (±0.11)	4.42 (±0.09)	.117	0.90 (±0.11)***	0.35 (±0.09)***	< .001
Action Planning (5 items)	0.95	4.27 (±0.17)	4.71 (±0.14)	.047	1.44 (±0.19)***	0.93 (±0.16)***	.042
Coping Planning (3 items)	0.92	3.06 (±0.16)	3.35 (±0.14)	.174	1.67 (±0.18)***	1.41 (±0.16)***	.293
Maintenance Self-efficacy (3 items)	0.97	3.99 (±0.16)	4.44 (±0.14)	.030	1.21 (±0.16)***	0.43 (±0.14)**	< .001
Recovery Self-efficacy (7 items)	0.93	4.86 (±0.12)	4.82 (±0.10)	.794	0.95 (±0.14)***	0.75 (±0.12)***	.263
Behavioral Intention [g] (1 item)	-	69.43 (±2.30)	69.62 (±1.98)	.995	13.37 (±2.66)***	4.48 (±2.28)	.012

Note.
[a] Group Lifestyle Balance (GLB) standard intervention group
[b] Group Lifestyle Balance Plus (GLB+) augmented intervention group
[c] Comparison of means using a mixed model with the interaction term for fixed effect for between-group comparison at baseline
[d] Comparison of means using a mixed model with the interaction term for fixed effects to compare the between-group change from baseline to four-month follow-up (month four – baseline)
[e] Multicomponent score with higher scores indicating greater perceived risk for type 2 diabetes
[f] Response options ranged from 1 = "not at all true" to 7 = "exactly true" except where noted otherwise
[g] One-item measure with response options from 0% = "not at all confident" to 100% = "extremely confident"
Within-group change from baseline **p < .01; ***p < .001

Table 3
Least squares mean (±SE) for dietary intake and PA by treatment group at baseline and four months

Dietary Intake (servings in equivalent measures)						
Food Group [a]	**Baseline**			**Change at four months**		
	GLB [b] (n = 77)	**GLB+ [c] (n = 103)**	***p*-value [d]**	**GLB (n = 77)**	**GLB+ (n = 103)**	***p*-value [e]**
Energy (kilocalories)	2011 (±66.75)	1797 (±57.72)	.016	-429 (±57.5)***	-313 (±49.72)***	.130
Total fat (percent energy)	39.22 (±0.66)	38.48 (±0.57)	.393	-2.92 (±0.67)***	-2.38 (±0.58)**	.538
Fruit (cup)	1.24 (±0.11)	1.23 (±0.10)	.942	0.08 (±0.10)	-0.01 (±0.08)	.481
Vegetable (cup)	2.07 (±0.13)	1.82 (±0.11)	.137	0.08 (±0.11)	-0.10 (±0.10)	.242
Protein (ounce)	5.52 (±0.27)	5.20 (±0.23)	.364	-0.82 (±0.25)**	-0.78 (±0.22)***	.904
Dairy (cup)	1.93 (±0.09)	1.65 (±0.08)	.024	-0.49 (±0.09)***	-0.35 (±0.08)***	.251
Grain (ounce)	5.59 (±0.25)	4.87 (±0.21)	.030	-1.12 (±0.21)***	-0.78 (±0.18)***	.211
Solid fat (gram)	40.33 (±1.58)	35.94 (±1.36)	.037	-11.69 (±1.44)***	-8.59 (±1.25)***	.106
Oil (gram)	28.92 (±1.25)	23.38 (±1.08)	< .001	-8.07 (±1.25)***	-5.11 (±1.08)***	.074
Added sugar (teaspoon)	10.43 (±0.62)	9.54 (±0.53)	.276	-3.32 (±0.56)***	-2.46 (±0.49)***	.254
Minutes of Physical Activity (moderate-intensity activity)						
	Baseline			**Change at 4-months**		
	GLB (n = 71)	**GLB+ (n = 91)**	***p*-value**	**GLB (n = 71)**	**GLB+ (n = 91)**	***p*-value**
Minutes [f]	203.72 (±21.58)	169.04 (±18.87)	.228	83.7 (±21.03)***	18.6 (±18.55)	.022

Note.
[a] Four participants were removed from the analysis due to implausible energy intake (> 4000 kcal/day)
[b] Group Lifestyle Balance (GLB) standard intervention group
[c] Group Lifestyle Balance Plus (GLB+) augmented intervention group
[d] Comparison of means using a mixed model with the interaction term for fixed effect for between-group comparison at baseline
[e] Comparison of means using a mixed model with the interaction term for fixed effects to compare the between-group change from baseline to four-month follow-up (month four – baseline)
[f] Nineteen participants did not have usable Fitbit data at one or both timepoints.
Within-group change from baseline $^{**}p < .01$; $^{***}p < .001$

of fruits and vegetables. These findings indicate that participants reduced intake of energy-dense foods, while maintaining fruit and vegetable consumption, consistent with study goals. Thus, both GLB and GLB+ were effective in promoting dietary change.

Both treatment groups reported statistically significant increases in planning behaviors regarding purchasing, preparing, and consuming lower calorie and fat foods while engaging in PA. Action and coping planning are two processes that translate intentions into behavioral action (Sniehotta et al., 2005). Current findings concur with previous research regarding action and coping planning. Women enrolled in the commercial WW program (formerly Weight Watchers) were prompted to make detailed weekly action and coping plans for dietary intake and PA (Luszczynska et al., 2007). Compared to the standard WW program, women who developed action and coping plans, in addition to the commercial program, reported implementing those strategies more frequently post-intervention. At two months, women in the treatment group lost a mean of 4.2 kg compared to a mean of 2.1 kg lost by women in the control group ($p < .01$). There were similar results in planning for PA among adults in a separate workplace health promotion intervention (Keller et al., 2016). Participants received online modules containing activities regarding self-efficacy (i.e., reflection on past success, vicarious experiences, and verbal persuasion through testimonials), action and coping planning (i.e., developing a weekly calendar of action plans, anticipating obstacles, and coping responses), and developing a PA network (i.e., identifying partners for goal sharing). At three months, the increase in PA observed was related to planning behaviors. Taken together, these findings suggest that planning may serve a key role and intervention target.

Several theoretical models, including HAPA, highlight the intention-behavior gap as a major impediment to behavioral change (Sheeran & Webb, 2016; Zhang et al., 2019). Planning is viewed as a critical tool that allows people to act more in line with their intention. Action planning can promote initiation of the target behavior by specifying when, where, and how to act by linking behavior to specific environmental contexts. Coping planning can protect behavioral intentions from derailment by anticipating personal risk situations and developing suitable coping responses in advance. Whereas effective action planning requires accurately anticipating situations that afford the target behaviors, effective coping planning depends on accurately anticipating personal risk situations (e.g., habits, temptation) based on experience (Sniehotta et al., 2005). These planning behaviors may serve as a modifiable self-regulatory practice and effective target for translating intentions into successful action. Future research is needed to determine whether action and/or coping planning mediate the change in dietary intake and PA once an intention to act has been established.

We also found a statistically significant improvement in action, maintenance, and recovery self-efficacy in both treatment groups in our study. In the HAPA, action self-efficacy is considered a predictor of behavioral intention, and maintenance and recovery self-efficacy are considered predictors of the initiation and maintenance of behavior (Zhang et al., 2019). However, few intervention studies distinguish among changes in action, maintenance, and recovery self-efficacy. Given the HAPA supposition that different tasks require a different form of self-efficacy to achieve mastery, understanding where self-efficacy can be strengthened, and through which behavioral change approach, is important for developing effective interventions (Schwarzer et al., 2007; Tang et al., 2019). Additional research is needed to determine whether maintenance and/or recovery self-efficacy is the most influential predictor(s) of choosing a lower energy diet and/or engaging in moderate-intensity PA.

Despite these gains, only four participants in the entire sample reduced total fat intake to < 25% of energy intake. In the DPP, mean percent energy intake from fat was 27.5% at one-year follow-up but the proportion of participants who achieved the dietary goal was not reported (The Diabetes Prevention Program Research Group, 2002). DPP participants who made the greatest reduction in fat intake in the first year of the trial had lower fat intakes at nine-year follow-up (Davis et al., 2013). The difficulty in meeting the dietary fat goal likely represents the fat content of the food supply. Participants in our study reported anecdotally that they experienced difficulty meeting their individual dietary fat goal. However, for every 5% reduction in fat intake, the incidence of type 2 diabetes was reduced by 25% in the DPP regardless of goal attainment (Hamman et al., 2006).

Moreover, GLB+ participants did not report a statistically significant increase in intention to achieve the PA goal and reported less gain in action and maintenance self-efficacy for PA compared to GLB participants. In addition, GLB+ participants did not significantly increase moderate-intensity PA at follow-up. Although no single approach has been found to be most effective in influencing self-efficacy (Tang et al., 2019), Bandura suggests self-efficacy is influenced by: (1) mastery experiences; (2) vicarious experiences; (3) verbal persuasion; and (4) physiological and emotional arousal (Bandura, 1977). The GLB+ intervention incorporated guided instruction, modeling, goal setting, action and coping planning, self-monitoring, feedback, and encouragement from program staff to strengthen efficacious beliefs. However, the GLB+ intervention may need to incorporate group-based PA sessions led by study staff with behavioral modeling, graded tasks, and personalized feedback to promote greater PA (Williams et al., 2011). The social support provided at worksites through group-based PA sessions also may promote comradery and feelings of belonging. In addition, greater individual problem solving regarding how to incorporate PA into one's routine may be needed to overcome individual obstacles to change (e.g., being active when experiencing stress).

Although intention does not consistently predict behavioral change (Scholz et al., 2008), what is worth noting is the significant increase in intention to consume a low-fat diet and engage in PA in GLB compared to GLB+. One possible explanation for the difference between treatment groups may be attributed to the early weight loss experienced by GLB participants (Miller et al., 2022). Losing > 2.5% of body weight in the first month of treatment may serve as mastery reinforcement and increase self-efficacy to continue setting and acting on intentions. These results are consistent with previous research that compared measures in women with obesity who achieved ≥ 5% weight loss to women who did not (Annesi et al., 2015). Participants who lost ≥ 5% of their weight at six months reported significant increases in self-regulation, self-efficacy, physical self-concept, and body satisfaction. In another study, PREVIEW, those who achieved ≥ 8% weight loss at eight weeks were considered "achievers," whereas those who lost < 8% were considered "non-achievers" (Huttunen-Lenz et al., 2018). "Achievers" reported greater behavioral intention and self-efficacy for dietary intake and PA. Future research in this area is warranted, perhaps via ecological momentary assessment to capture change as it occurs in real time, to determine if early weight loss success reinforces the cognitive-behavioral and self-regulatory skills needed to set and act on behavioral intentions.

Finally, we modified intervention delivery during the trial due to the pandemic. However, there were no statistically significant differences in the change in outcomes for either treatment group by delivery method (except for outcome expectancies in GLB+; data not shown). Therefore, the interventions could be offered either in-person or via videoconference, which allows participants to choose the delivery method they prefer. Also, worksites could offer the interventions in both formats to potentially increase dissemination.

Strengths and Limitations

Despite promising study findings, we have limitations to note. The sample had limited racial and ethnic diversity, enrolled a smaller proportion of men compared to women, and consisted of a well-educated sample. Thus, intervention impact in more diverse samples of adults with prediabetes is needed to increase the generalizability of findings. The assessment of dietary intake using food frequency questionnaires may be affected by recall bias and social desirability (Shim et al., 2014). In addition, the food frequency questionnaire assessed usual dietary intake during the previous year and captured intake beyond the four-month timeframe of the trial. The assessment of PA relies upon the number of active days captured based on device wear time and frequency of data synchronization. Furthermore, Fitbit only counts active minutes, if the bout of movement is $\geq$ 10 consecutive minutes; short spontaneous increases of movement (e.g., brief walk) are not recorded. Thus, total active minutes of PA may be underestimated in the current study. Although the HAPA instrument demonstrated adequate internal consistency, additional research is needed for validation of constructs and to assess the test-retest reliability of constructs with a no contact control group.

Implications for Health Behavior Research

The adaptive intervention facilitated treatment and included self-regulatory strategies for achieving behavioral change. Both GLB and GLB+ participants experienced significant reduction in energy intake and improvement in dietary intake across food groups, key behavioral targets. Participants in both treatment groups experienced improvement in HAPA measures and fat intake, and GLB participants increased moderate-intensity PA consistent with study goals. These results demonstrate promising evidence of the usefulness of adaptive research designs in improving intervention effectiveness.

Future research is recommended to identify mediators (e.g., action planning) of the change in behavior and moderators (e.g., sex) of change for strengthening intention formation and for enacting behavioral change following intention formation. Mediators, such as action planning, indicate that behavioral change (e.g., calorie intake) occurs with greater action planning once an intention to change is sufficiently established. Moderators, such as sex, would indicate whether men benefit more from planning dietary intake in advance than women. The causal sequence of change in social-cognitive constructs within the HAPA framework following intervention implementation is needed to determine effective targets of focus for behavioral interventions among people with prediabetes. Worksites can be viable avenues for delivering diabetes prevention programs tailored to employees through adaptive interventions. More effective intervention tailoring may be advantageous for other high-risk groups at worksites. Lifestyle change among people with prediabetes may promote risk reduction for type 2 diabetes and potentially improve quality of life.

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Discussion Questions

The Health Action Process Approach (HAPA) provides guidance for translating a behavioral intention into action via planning and self-efficacy. How can interventionists leverage action and coping planning and maintenance and recovery self-efficacy during program implementation to promote behavioral action?

The Health Action Process Approach (HAPA) is one of many social-cognitive theoretical frameworks. Unlike other frameworks, the HAPA distinguishes between the motivation to act (no clear intention established) and volitional behavioral action (post-intention formation). What are the best approaches for identifying individuals who have versus have not set an intention to change and for tailoring intervention messages to each group accordingly?

Ethical Approval

All procedures were followed in accordance with the ethical standards of the Institutional Review Board at the sponsoring university; participants provided written informed consent.

Conflict of Interests

The authors have no conflicts of interest to declare.

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