The development of an ecological momentary intervention to improve reward-related eating in adult women

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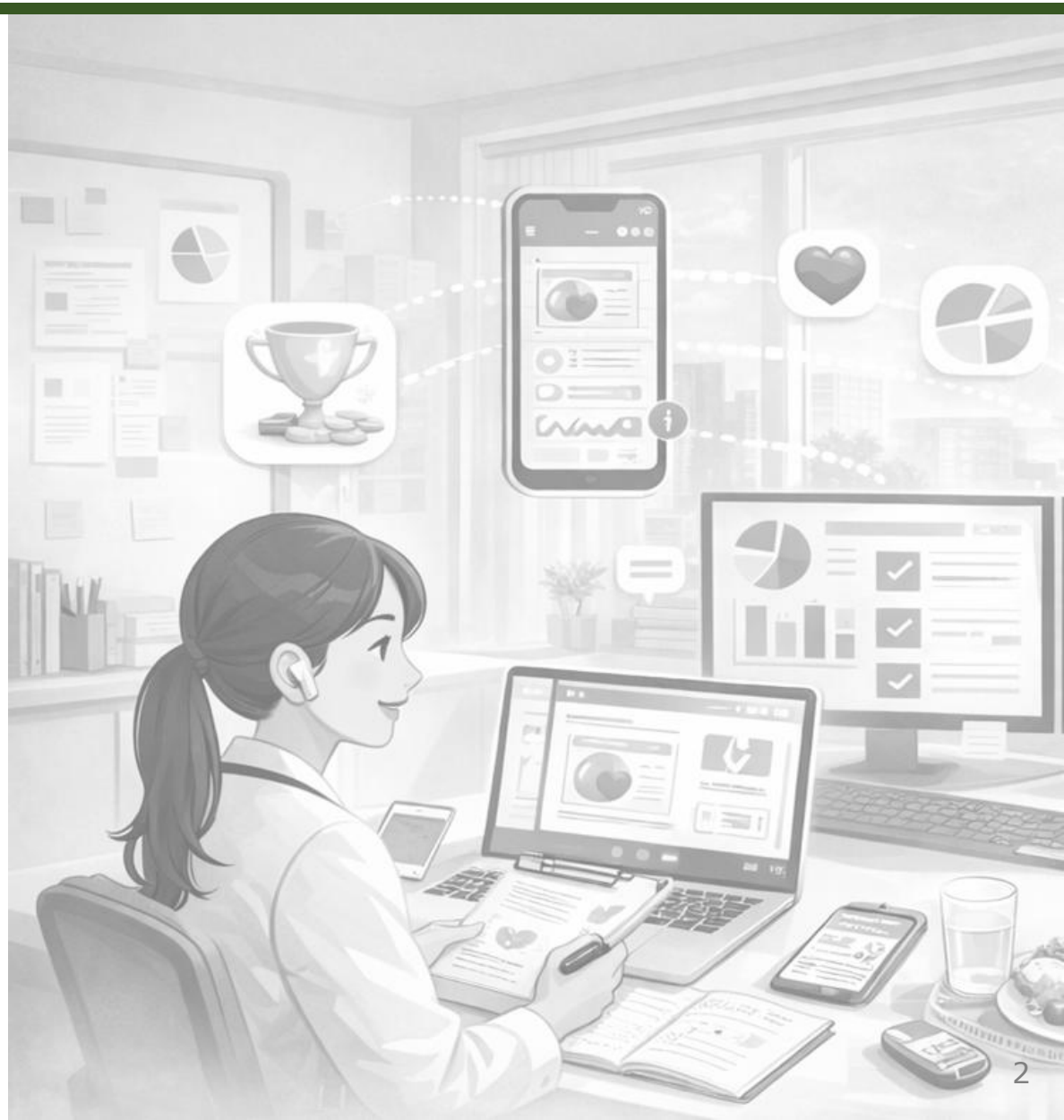

Ⅰ. Background and objective

Background

1. The need for early management of dietary behavior problems among women in early adulthood

- According to the Korea National Health and Nutrition Examination Survey, dietary patterns among adult women have stagnated or worsened (Korea Disease Control and Prevention Agency, 2023).
- Although the obesity prevalence among women was lower than that among men, unlike men, women showed a stepwise increase in obesity prevalence with advancing age (Kim et al., 2021).

2. Importance of reward-related eating (RRE) among obesity-related dietary behaviors in women

- RRE refers to eating behavior driven by psychological factors rather than physiological hunger (Epel et al., 2014).
- Individuals with elevated levels of RRE tend to show higher BMI values and greater vulnerability to type 2 diabetes (Mason et al., 2017).
- Women may be more vulnerable to high levels of RRE, a behavioral tendency linked to weight gain, overeating, and long-term obesity risk (Yang and Kwon, 2021; Mahlberg et al., 2024).

3. Developing a Social Cognitive Theory (SCT)-Guided Ecological Momentary Intervention (EMI) for RRE

- EMI is a behavior change intervention that provide support in real time at moments of heightened need (Heron & Smyth, 2010).
  - EMI, typically delivered via mobile devices such as smartphones or wearables, provides timely cues, feedback, or strategies to support behavior change in daily life (Heron & Smyth, 2010; Nahum-Shani et al., 2016).
- Because RRE fluctuates across time and contexts, EMIs may be particularly effective for addressing RRE in daily life.
- SCT proposes reciprocal determinism as a useful theoretical framework for understanding the mechanisms underlying RRE, which holds that behavior is the outcome of continuous interactions between environmental, behavioral, and personal factors (Bandura, 1986).

Objective

This study aimed to develop an SCT-guided EMI targeting RRE and evaluate its effectiveness among adult women.

Ⅱ. Methods

Research design

Mixed method experimental design

Experimental Quantitative Design

QUAN

Data Collection and Analysis

- **Baseline (Phase 1 and Phase 2) and Endline Surveys**
- **A three-week EMI with monitoring**

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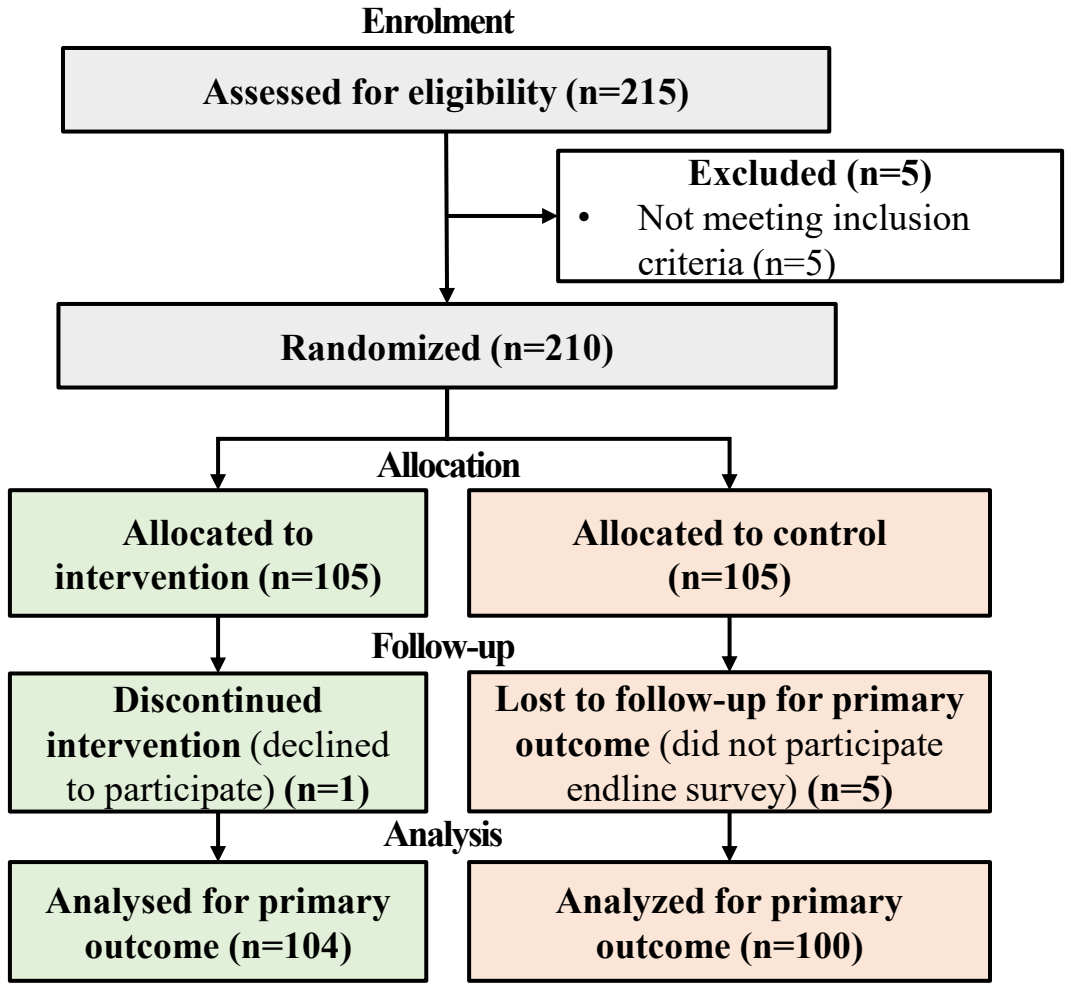
Data Collection and Analysis

Before the intervention	During the intervention	After the intervention

- **Pre-, mid-, and post-intervention Focus Groups**

→ Interpretation **QUAN (qual)**

CONSORT Flow Diagram*



* The CONSORT (Consolidated Standards of Reporting Trials) statement was designed to improve the quality of reporting and provides a minimum set of items to be included in a report of a randomized trial.

Ⅱ. Methods

Study flow diagram

Needs asssessment	Development	Implementation	Evaluation
Before the intervention		During the intervention	After the intervention
		Process evaluation	Outcome evaluation
Intervention group	Baseline survey, Pre-intervention Focus groups	3-week EMI with monitoring, Mid-intervention Focus groups	Endline survey, Post-intervention Focus groups
Control group	Baseline survey	3-week minimal intervention	Endline survey

3-week intervention targeted three RRE subfactors (Epel et al., 2014)

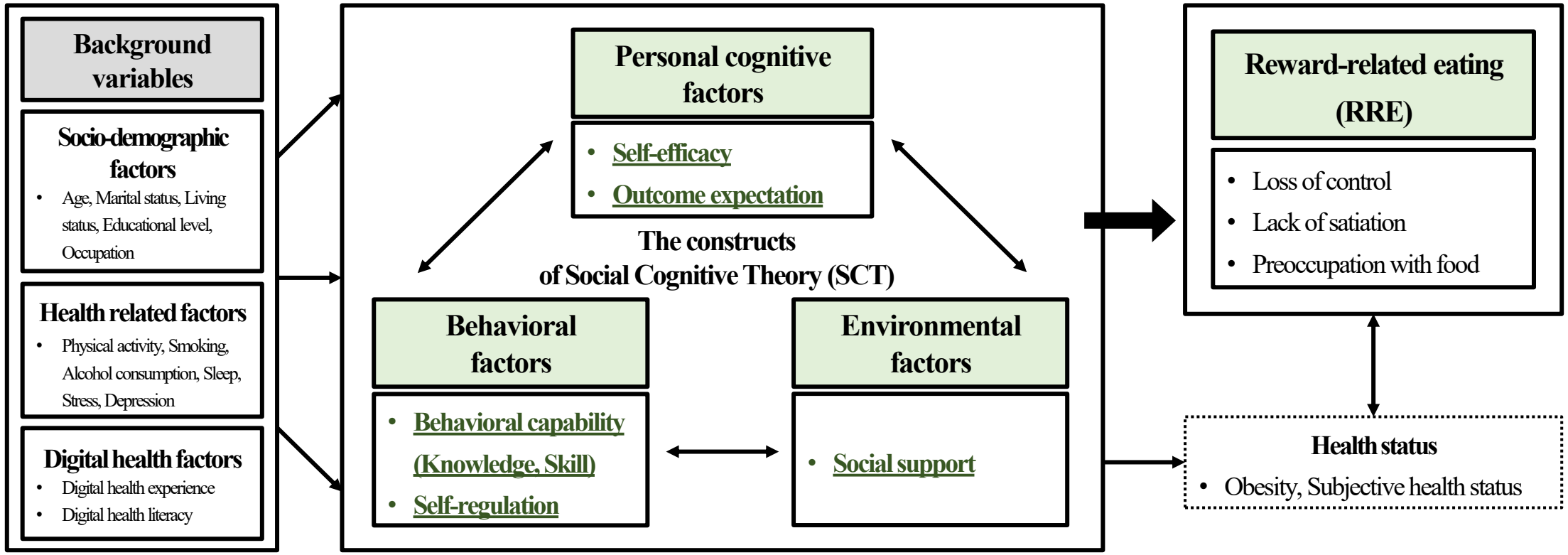
① **Loss of control (overeating) (LC):** the extent to which individuals feel unable to regulate their eating and continue or increase consumption even in the absence of hunger

② **Lack of satiation (LS):** experiencing persistent hunger and difficulty feeling full

③ **Preoccupation with Food (PF):** the degree to which individuals become absorbed in thoughts about food and are unable to stop such thoughts despite efforts to do so

Ⅱ. Methods

Study framework



Data Analysis

Quantitative findings were derived from **linear mixed-effects models** and **multi-group structural equation modeling**, while qualitative findings were analyzed using the framework method and integrated with the quantitative results through a **joint display.**

Ⅱ. Methods

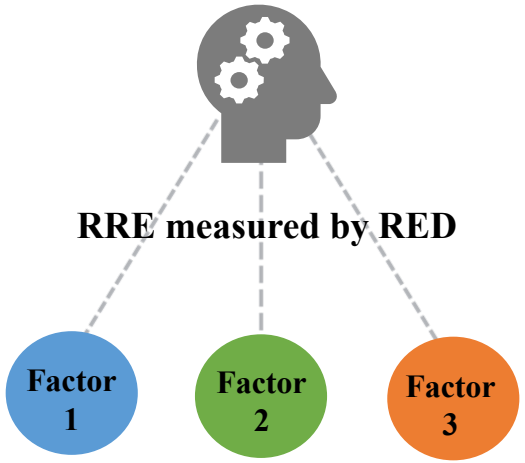
Logic model of change

Inputs	Activities	Outputs	Outcomes		
			Short-term	Mid-term	Long-term
• Intervention platform: smartphone messaging app • Materials design platform • Survey and monitoring platform • Server • Data collection system and database • Implementer • Guidelines • Budget	• Participant recruitment • Pre-, mid-, and post-intervention focus groups • Baseline-Endline survey • EMI platform registration • **Intervention for RRE control** - **Daily content delivery**: brief messages, missions, participant-generated content(Tips and peer encouragement messages) - **Weekly monitoring and feedback** - **Incentive system**	• Recruitment materials for the intervention program • Quantitative data: survey and monitoring data, log data • Qualitative data: focus group data • Delivered intervention content	**Personal cognitive factor** • Self-efficacy • Outcome expectations **Behavioral factor** • Behavioral capability – knowledge, skills • Self-regulation **Environmental factors** • Social support	**Eating behavior** • **Reward-related eating behavior** *(Primiary outcome)* : 1) Loss of control, 2) Lack of satiation, 3) Preoccupation with food	**Health status** *(Secondary outcome)* • Obesity • Subjective health status

Ⅱ. Methods

EMI

Data collection



- ✓ **RED Factor 1**: Loss of control over eating (LC)
- ✓ **RED Factor 2**: Lack of satiety (LS)
- ✓ **RED Factor 3**: Preoccupation with food (PF)

RED: Reward-Based Eating Drive Scale (5-point Likert scale) to meausre reward-related eating (RRE)

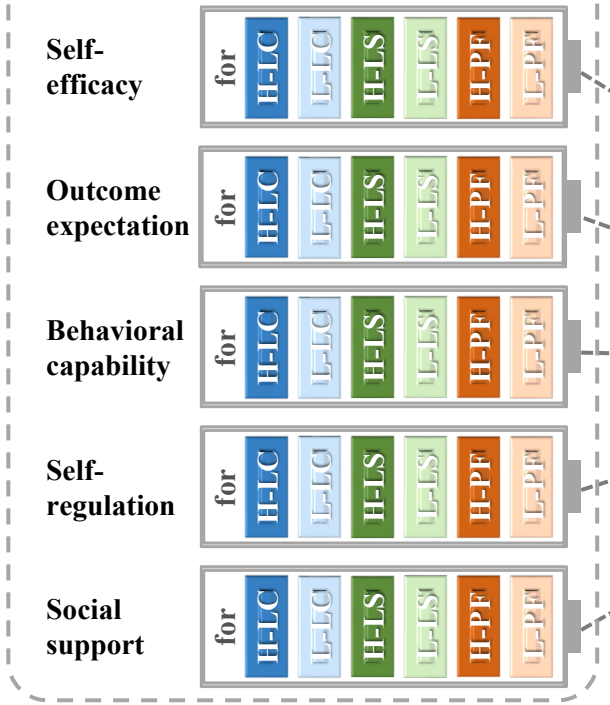
Segmentation

	Factor 1	Factor 2	Factor 3
Cluster 1	H-LC	H-LS	H-PF
Cluster 2	L-LC	H-LS	H-PF
Cluster 3	H-LC	L-LS	H-PF
Cluster 4	H-LC	H-LS	L-PF
Cluster 5	H-LC	L-LS	L-PF
Cluster 6	L-LC	H-LS	L-PF
Cluster 7	L-LC	L-LS	H-PF
Cluster 8	L-LC	L-LS	L-PF

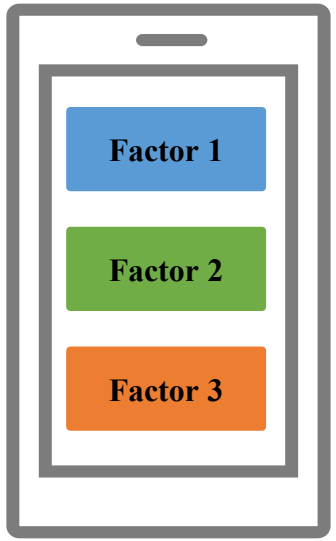
- ✓ **H-:** High RED (≥3)
- ✓ **L-:** Low RED (<3)

Intervention personalization

Program content packages designed to enhance:



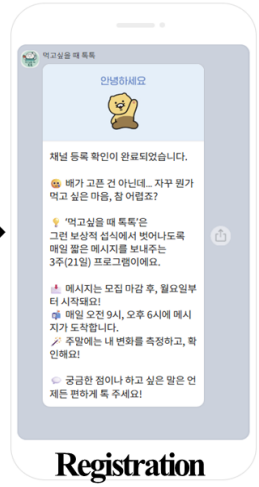
Personalized content modules for each cluster



Ⅱ. Methods

EMI

Participant registration



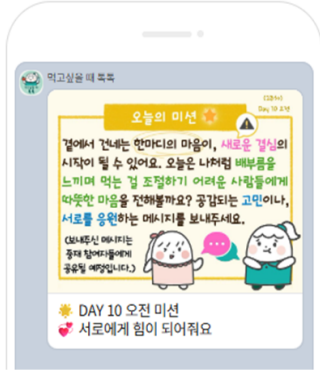
Registration confirmation

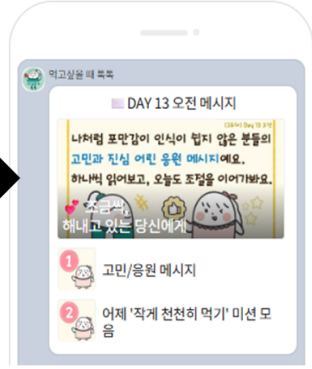
Intervention start notification: Participation protocol provided

[H-RED] [L-RED]

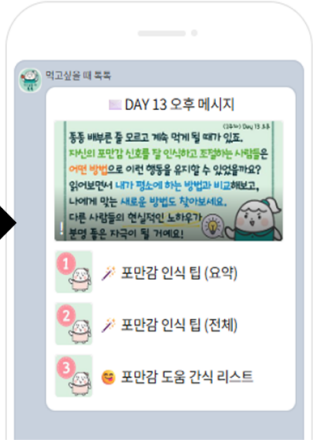
Messages

Missions



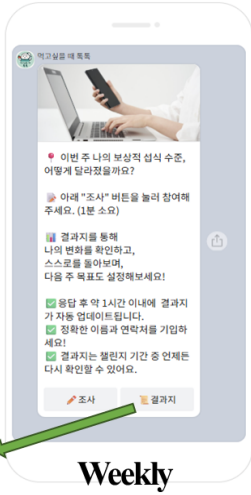


Mission for social support



Message for social support

Announcement of reward recipients



Weekly monitoring

Ⅱ. Methods

EMI

Weekly composition of daily content

No.	SCT Construct	BCTs Applied	Description	Activity
1	Behavioral capability (Awareness-knowledge)	Information about health consequences	Provides awareness-knowledge related to RRE	Reply to message
2	Self-efficacy	Credible source	Enhances confidence through verbal persuasion from an expert researcher regarding the ability to improve RRE	Reply to message
3	Self-efficacy	Goal setting, Action planning	Enhances confidence by setting small step goals for improving RRE and achieving mastery experiences	Submit "self-efficacy" mission
4	Outcome expectations	Information about social and environmental consequences	Promotes awareness of the positive consequences of improving RRE for social relationships, quality of life, and environmental aspects	Reply to message
5	Social support	Social support (emotional)	Encourages participants to provide emotional support (encouraging messages) or informational support (tips) to other participants for improving RRE	Submit "social support" mission: (High-RED) Send encouraging messages; (Low-RED) Send tips
6	Outcome expectations	Pros and cons	Strengthens positive outcome expectations by listing the advantages and disadvantages of improving RRE	Reply to message
7	Behavioral capability (How-to-knowledge)	Instruction on how to perform the behavior	Provides how-to-knowledge related to RRE	Reply to message
8	Behavioral capability (Principles-knowledge)	Information about Antecedents	Provides principles-knowledge related to RRE	Reply to message

Ⅱ. Methods

EMI

Weekly composition of daily content

No.	SCT Construct	BCTs Applied	Description	Activity
9	Behavioral capability (Skills)	Behavioral practice	Presents and trains behavioral skills for improving RRE	Submit "skills" mission
10	Social support	Social support (instrumental)	Encourages the use of instrumental support from family or friends to assist actual behaviors for improving RRE	Reply to message
11	Social support	Social support (emotional and appraisal)	Provides emotional support for improving RRE by sharing encouraging messages, which are social support mission results submitted by individuals who have difficulty improving RRE, and provides appraisal support for improving RRE by sharing behavioral skills, which are skills mission results submitted by participants	Reply to message
12	Social support	Social support (informational)	Provides informational support for improving RRE by sharing tips, which are social support mission results submitted by individuals who are skilled at improving RRE	Reply to message
13	Self-regulation	Self-monitoring of behavior	Facilitates self-observation and self-evaluation for RRE	Participate in monitoring survey
14	Self-regulation	Self-monitoring of behavior, Feedback on behavior, Review behavior goal(s)	Facilitates self-reaction and goal setting for RRE.	Review the monitoring report and set the goal for the next week
15	Social support	Social support (practical), Social reward	Provides incentives for last week's program participation to completion achievers, including a universal small-value reward and a lottery-based high-value reward.	Check and receive the reward

Ⅱ. Methods

EMI

EMI-specific aspects*	Developed intervention
Intervention content	• Message-based content tailored to participants' RRE subfactor profiles using BCTs
Predetermined or adaptive	• Responsive content based on participants' interactions, including supportive messages, tips for reducing RRE, and behavioral skills training methods • Monitoring assessment results and feedback updates • Engagement tracking updates
Number of intervention prompts each day and the interval between each intervention	• Twice a day • 11:30 AM and 5:30 PM
Total time permitted to respond/receive/perform intervention before the prompt expires	• Responding to at least one of the two daily messages counted as full participation for that day. • If both messages were missed, participants could report reading them on the following day to receive participation credit. • Retroactive acknowledgment was not permitted for messages from the previous week.

EMI-specific aspects*	Developed intervention
System	• Smartphone messaging App (Kakaotalk Channel)
Delivery mode	• Images and short auto-playing video slides • Text-messages
Additional components used in combination with the app	• Survey and monitoring platform • Individual dashboard for monitoring results and weekly feedback • Individual engagement dashboard • Participant management and monitoring server
Models/frameworks/theories to inform the intervention design	• Social cognitive theory • Mixed methods within RCT experimental design
Incentives provided for intervention adherence	• Universal small-value reward • Lottery-based high-value reward

*EMI-specific aspects are based on the Methods section of the Checklist for Reporting EMA- and EMI-Specific Aspects in Behavior Change Experiments (Dao et al., 2021).

Ⅲ. Results

A Demographics of study participants

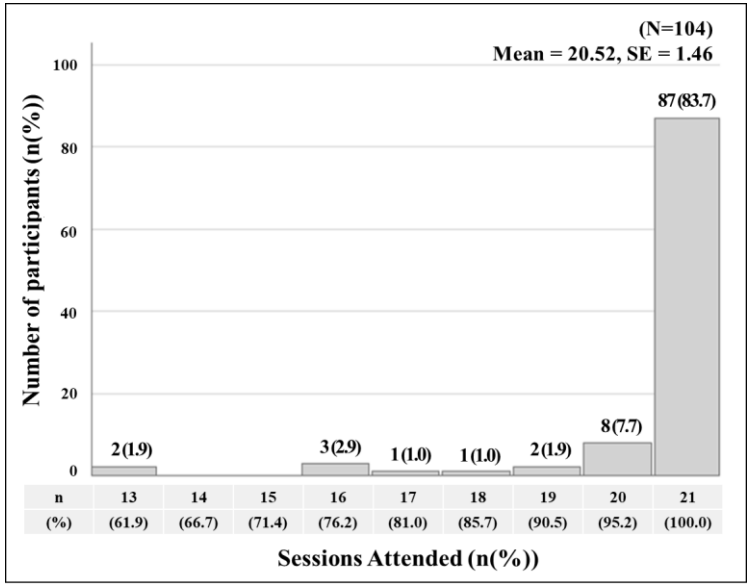
	n (%) or Mean ± Standard deviation			*p* value
	Total (N=204)	Intervention group (n=104)	Control group (n=100)	
Age (years)	27.94 ± 4.28	28.50 ± 4.48	27.36 ± 4.00	0.057
20s	136 (66.7)	62 (59.6)	74 (74.0)	**0.029**
30s	68 (33.3)	42 (40.4)	26 (26.0)	
Marrial status				
Not married	174 (85.3)	85 (81.7)	89 (89.0)	0.149
Married	29 (14.2)	19 (18.3)	10 (10.0)	
Divorce, widow, etc.	1 (0.5)	0 (0)	1 (1.0)	
Living status				
Alone	76 (37.3)	39 (37.5)	37 (37.0)	0.941
Not alone	128 (62.7)	65 (62.5)	63 (63.0)	
Education level				
High-school graduatee	34 (16.7)	15 (14.4)	19 (19.0)	0.450
College/University graduate	129 (63.2)	65 (62.5)	64 (64.0)	
Graduate school graduate	41 (20.1)	24 (23.1)	17 (17.0)	
Occupation				
Managers and Professionals	26 (12.7)	9 (8.7)	17 (17.0)	0.302
Administrative Workers	63 (30.9)	38 (36.5)	25 (25.0)	
Sales and Service Workers	8 (3.9)	5 (4.8)	3 (3.0)	
Skilled Trades and Production Workers	2 (1.0)	1 (1.0)	1 (1.0)	
University/Graduate Students	69 (33.8)	32 (30.8)	37 (37.0)	
Others (e.g., unemployed individuals, job seekers, homemakers)	36 (17.6)	19 (18.3)	17 (17.0)	
Social cognitive theory constructs				
Self-efficacy (Points, range: 1-5)	2.40 ± 0.78	2.40 ± 0.79	2.39 ± 0.78	0.951
Outcome expectation (Points, range: 1-5)	3.87 ± 0.64	3.87 ± 0.68	3.86 ± 0.59	0.970
Behavior capability				
Knowledge (Points, range: 0-9)	5.34 ± 1.58	5.58 ± 1.52	5.10 ± 1.62	**0.031**
Skills (Points, range: 1-5)	2.57 ± 0.76	2.59 ± 0.80	2.55 ± 0.71	0.732
Self-regulation (Points, range: 1-5)	2.91 ± 0.62	2.92 ± 0.62	2.90 ± 0.62	0.789
Social support (Points, range: 1-5)	3.09 ± 0.80	2.98 ± 0.79	3.22 ± 0.80	**0.031**
Reward-related eating (Points, range: 1-5)	3.23 ± 0.76	3.28 ± 0.77	3.17 ± 0.74	0.346
Loss of control	3.76 ± 0.80	3.78 ± 0.79	3.73 ± 0.80	0.632
H-LC	159 (77.9)	80 (76.9)	79 (79.0)	0.721
L-LC	45 (22.1)	24 (23.1)	21 (21.0)	
Lack of satiation	2.69 ± 0.91	2.74 ± 0.9	2.64 ± 0.92	0.401
H-LS	60 (29.4)	33 (31.7)	27 (27.0)	0.458
L-LS	144 (70.6)	71 (68.3)	73 (73.0)	
Preoccupation with food	2.83 ± 0.91	2.91 ± 0.94	2.75 ± 0.88	0.194
H-PF	82 (40.2)	46 (44.2)	36 (36.0)	0.291
L-PF	122 (59.8)	58 (55.8)	64 (64.0)	
Health status				
Obesity				
BMI (kg/m²)	22.38 ± 3.93	22.06 ± 3.89	22.73 ± 3.96	0.224
Underweight	22 (10.8)	12 (11.5)	10 (10.0)	0.434
Normal weight	113 (55.4)	62 (59.6)	51 (51.0)	
Overweight	27 (13.2)	13 (12.5)	14 (14.0)	
Obese	42 (20.6)	17 (16.3)	25 (25.0)	
Subjective health status (Points, range: 1-5)	3.08 ± 0.71	3.07 ± 0.69	3.09 ± 0.74	0.820

All variables of SCT constructs and RRE behaviors were measured using five-point Likert-scale items. Higher scores indicate higher levels of each SCT construct. H-: High-score group, defined as a mean score ≥3; L-: Low-score group, defined as a mean score <3; BMI: Body mass index.

Ⅲ. Results

B Process evaluation: 1) Program process monitoring

Component	Key Findings
Program reach	• Mean attendance was 20.52 of 21 sessions. 83.7% completed all sessions, indicating excellent adherence.
Implementation fidelity	• All 48 planned messages were delivered as scheduled, with no technical errors or missed deliveries.
Participant satisfaction	• Overall satisfaction was high: 4.26 ± 0.59 out of 5. Participants positively evaluated the content, delivery, and materials.
Program management	• The program was delivered systematically through standardized feedback, Q&A support, and timely incentive delivery.
Quality control	• Mid-intervention FGs identified contextual needs and enabled real-time refinements in content, timing, and format.



(n=l00)

	Mean ± Standard deviation
Overall satisfaction with the intervention	4.25 ± 0.54
Perceived usefulness of the contents	4.24 ± 0.58
Satisfaction with the expertise and quality of the materials	4.28 ± 0.56
Satisfaction with the message and mission-based contents	4.23 ± 0.58
Perceived appropriateness of program delivery	4.23 ± 0.58
Satisfaction with the intervention method	4.27 ± 0.57
Total	4.26 ± 0.59

Each item was rated on a 5-point Likert scale, with higher scores indicating greater satisfaction.

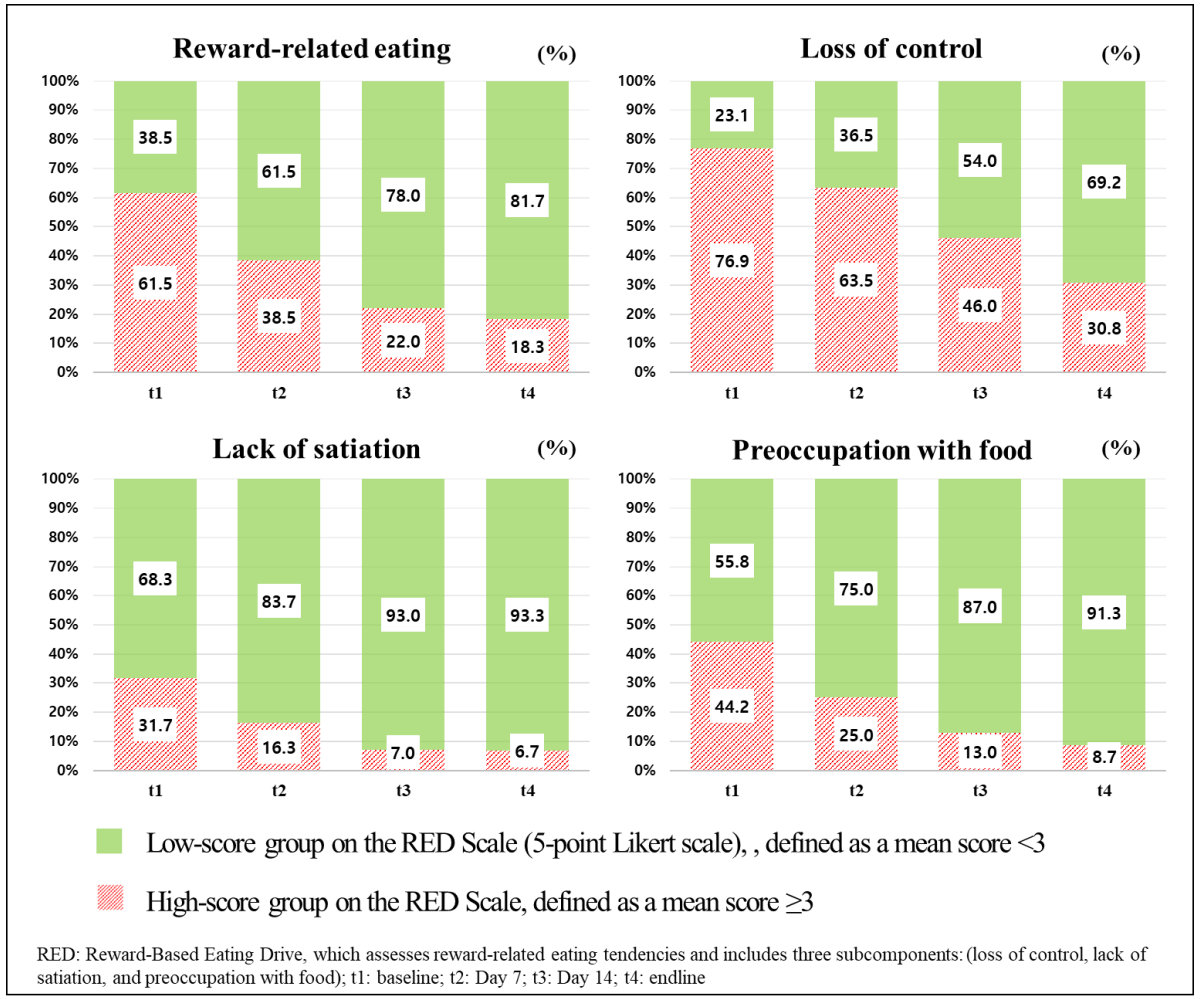
Ⅲ. Results

B Process evaluation: 2) Outcome Monitoring, 3) Integrative Interpretation

- All 104 participants completed RRE self-monitoring at baseline, day 7, and endline.
- The proportion of participants in **the low RRE score group increased from 38.5% to 81.7%.**
- Similar **improvements were observed in all RRE subdomains.**

- Quantitative monitoring showed a progressive reduction in RRE tendencies.
- Qualitative FGs explained how these changes occurred through:
  - ✓ Increased awareness of overeating cues
  - ✓ Improved self-monitoring
  - ✓ Anonymous peer support
  - ✓ Personalized researcher feedback

➢ Findings guided **real-time refinements, including earlier morning messages, visual cues, snack guidance, and optional peer-based support.**



RED: Reward-Based Eating Drive, which assesses reward-related eating tendencies and includes three subcomponents: (loss of control, lack of satiation, and preoccupation with food); t1: baseline; t2: Day 7; t3: Day 14; t4: endline

Ⅲ. Results

C Outcome evaluation

- Overall **RRE, LOC, LOS, and PWF decreased** from baseline to endline, indicating **steady improvement across the intervention period (p<0.001).**

	EMM ± SE				Time Effect	
	Baseline (t1)	**Day 7 (t2)**	**Day 14 (t3)**	**Endline (t4)**	***F*** **(*df*=3, 305)**	***p-value***
Reward-related eating	3.28 ± 0.07	2.91 ± 0.07	2.59 ± 0.07	2.29 ± 0.07	109.23	**<0.001**
Loss of control	3.78 ± 0.07	3.30 ± 0.07	2.95 ± 0.07	2.64 ± 0.07	111.44	**<0.001**
Lack of satiation	2.74 ± 0.08	2.44 ± 0.08	2.13 ± 0.08	1.86 ± 0.08	51.12	**<0.001**
Preoccupation with food	2.91 ± 0.08	2.58 ± 0.08	2.29 ± 0.08	1.97 ± 0.08	74.24	**<0.001**

EMM: estimated marginal mean; SE: standard error; *p-values* for the time effect were derived from linear mixed-effects models using Type III ANOVA with the Satterthwaite approximation for degrees of freedom.

	EMM					
	t1–t2	**t1–t3**	**t1–t4**	**t2–t3**	**t2–t4**	**t3–t4**
Reward-related eating	0.363***	0.683***	0.990***	0.319***	0.627***	0.308***
Loss of control	0.479***	0.832***	1.146***	0.352***	0.667***	0.314***
Lack of satiation	0.308***	0.610***	0.882***	0.303***	0.574***	0.271**
Preoccupation with food	0.334***	0.622***	0.945***	0.287***	0.611***	0.323***

EMM: estimated marginal mean; t1: baseline; t2: Day 7; t3: Day 14; t4: endline; *p-values* were obtained from linear mixed-effects models, with Bonferroni-adjusted pairwise comparisons between time points; ***p<0.001, **p<0.01

Ⅲ. Results

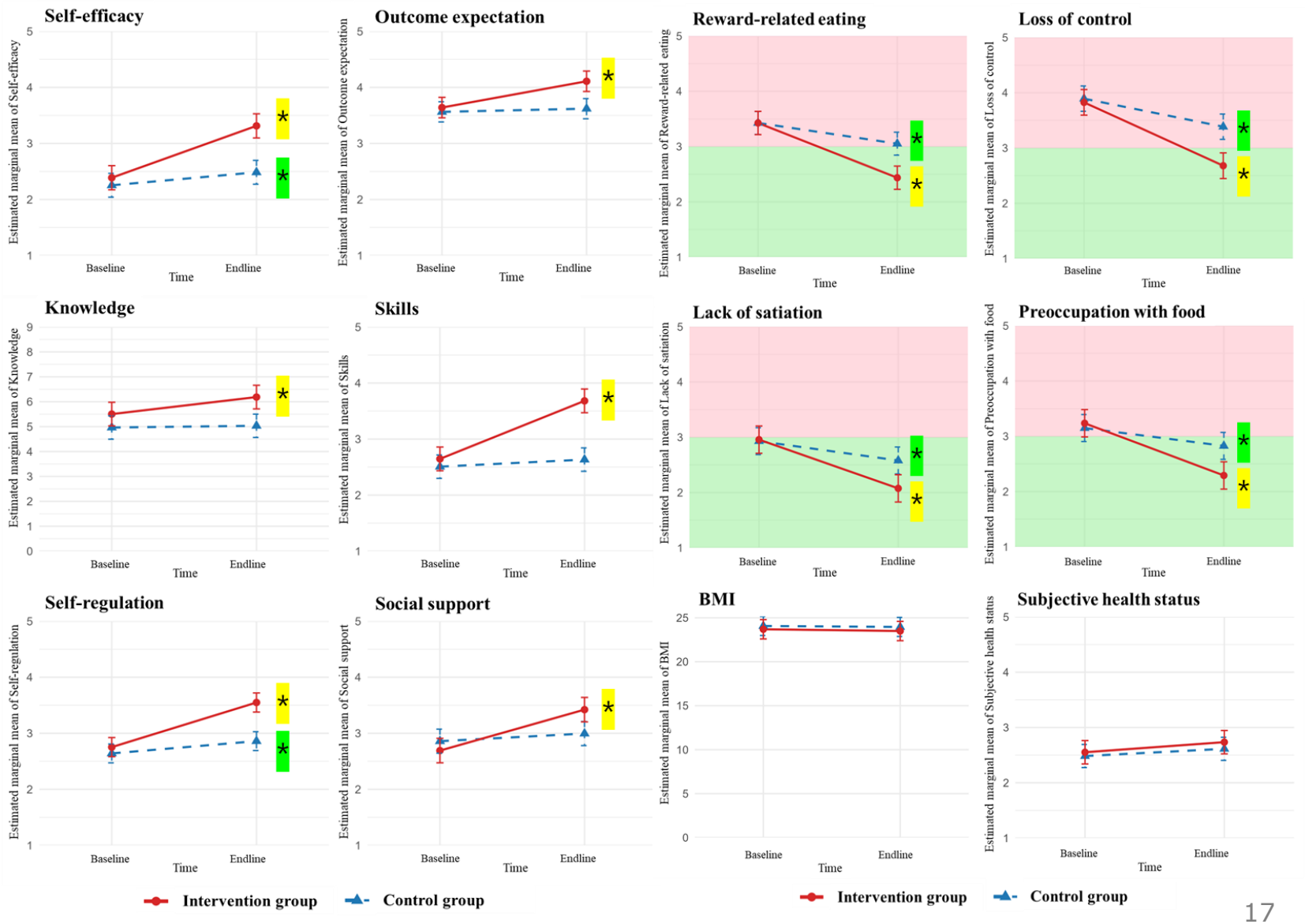
C Outcome evaluation

- Compared with the control group, the intervention group showed significantly **greater improvements in SCT constructs** and **greater reductions in RRE behaviors** from baseline to endline **(p<0.001)**.

N=204 (Intervention n=104, Control n=100)

	p value		
	Group effect	Time effect	Group × time effect
Self-efficacy	0.187	**0.021**	**<0.001**
Outcome expectation	0.364	0.504	**<0.001**
Knowledge	**0.018**	0.751	**0.048**
Skills	0.149	0.206	**<0.001**
Self-regulation	0.146	**0.007**	**<0.001**
Social support	0.081	0.190	**<0.001**
Reward-related eating	0.995	**<0.001**	**<0.001**
Loss of control	0.539	**<0.001**	**<0.001**
Lack of satiation	0.809	**0.003**	**<0.001**
Preoccupation with food	0.465	**0.005**	**<0.001**
BMI	0.465	0.831	0.900
Subjective health status	0.504	0.186	0.702

p values for within group baseline to endline changes were derived from covariate adjusted EMMs, and the group by time interaction was examined using covariate adjusted linear mixed effects models. Covariates included socio-demographic factors, health related factors, and digital health factors.

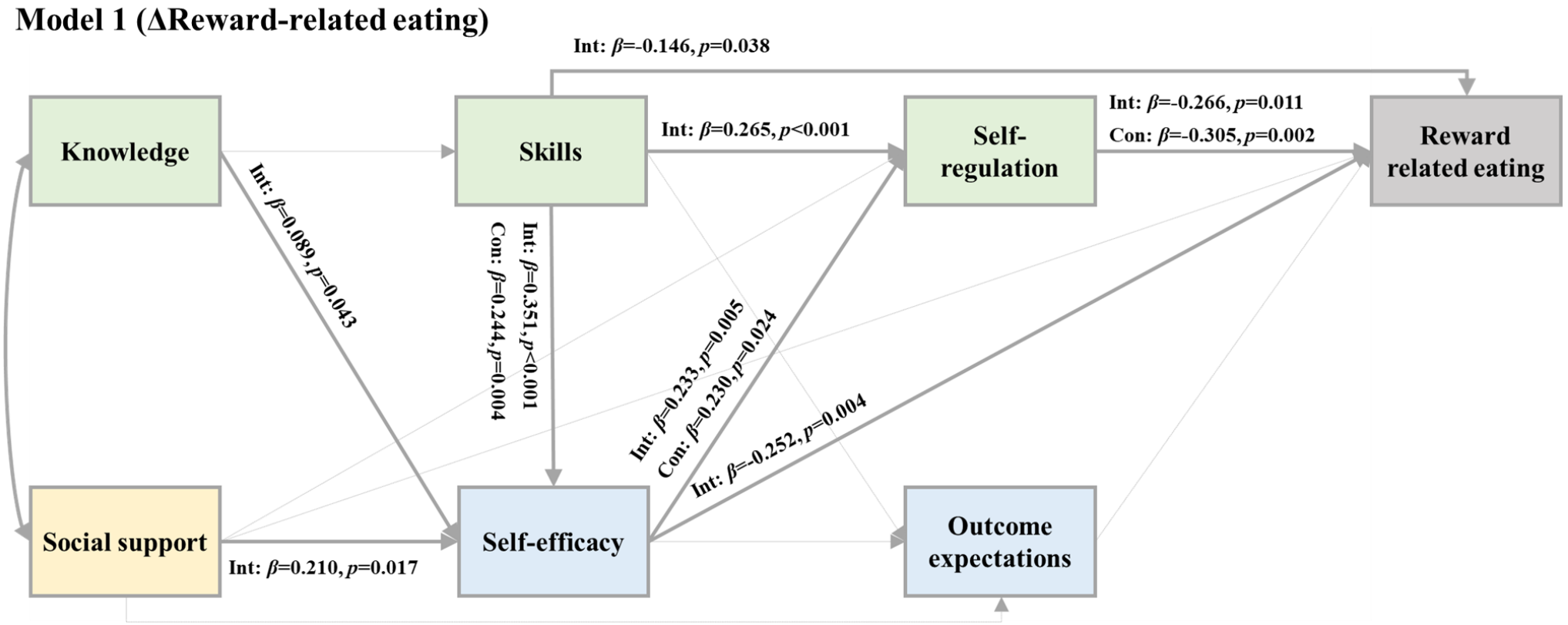


Asterisks indicate statistically significant within-group changes in EMMs within each group. $p < 0.05$.

Ⅲ. Results

C Outcome evaluation

- The intervention appeared to **reduce overall RRE** through improvements in **skills, self-efficacy, and self-regulation**, suggesting a broader **SCT-based mechanism of change** than observed in the control group.



Inv: intervention group; Con: control group; *p-values* correspond to tests of standardized regression coefficients (*β*) from multi-group SEMs, adjusted for socio-demographic, health related, and digital health factors.

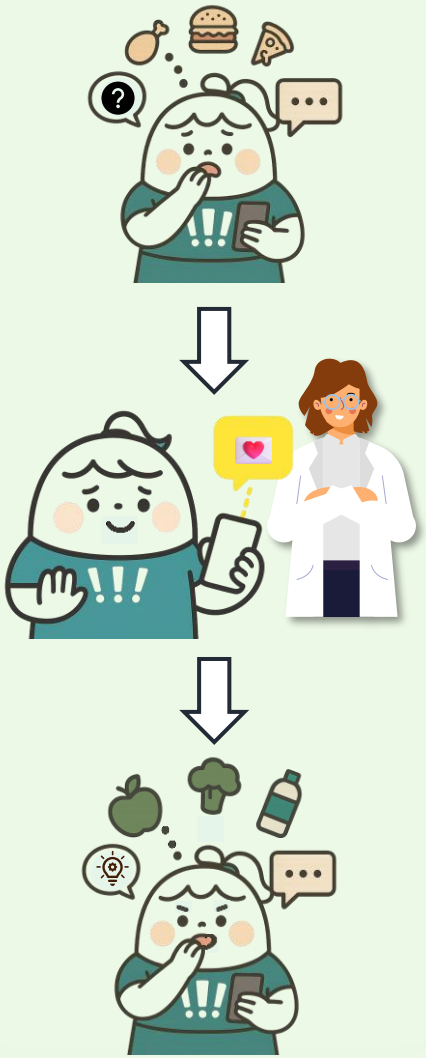
Ⅲ. Results

D Joint display of integration of post-intervention quantitative results and qualitative findings

Domain	Quantitative Results	Qualitative Findings	Integrated Interpretation
Self-efficacy (SE)	• Greater increase in Int. • Linked to lower RRE/PWF and higher SR	• Greater perceived control over eating	• Improved control, but weakened by vulnerability
Outcome expectations (OE)	• Increased only in Int. • Linked to lower LOS	• Benefits supported motivation	• Helped motivation and LOS improvement
Knowledge	• Increased only in Int. • Linked to higher SE	• Better awareness of satiety and triggers	• Supported SE, but insufficient alone
Skills	• Increased only in Int. • Linked to higher SE/SR and lower RRE/PWF	• Slowing eating and non-food substitution	• Translated awareness into action
Self-regulation (SR)	• Greater increase in Int. • Linked to lower RRE/LOS/PWF	• Stronger responders used strategies consistently	• Key proximal mechanism
Social support (SS)	• Increased only in Int. • Linked to higher SE	• Peer support enhanced engagement	• Worked indirectly through SE and motivation
Overall RRE	• Greater reduction in Int.	• Awareness, skills, and structure supported change	• Integrated strategies reduced RRE
Loss of Control (LOC)	• Greater reduction in Int.	• Stress and emotional reactivity limited gains	• Need stronger emotion-focused support
Lack of Satiation (LOS)	• Greater reduction in Int.	• Satiety awareness and pacing helped	• Physiological insight supported change
Preoccupation with Food (PWF)	• Greater reduction in Int.	• Reframing and substitution helped	• Persistent cues limited gains

Int. = intervention group

Ⅳ. Conclusions



Lessons learned

- An **SCT grounded in EMI** effectively **reduced RRE among adult women**.
- These findings support the potential of theory based **digital EMIs for addressing obesity-related eating behaviors** and highlight the need for further evaluation of individual intervention components.

Relevance to HPH

- **RRE** increases the risk of **obesity** and related **chronic diseases** among **women in early adulthood.**
- **Innovative health service-based interventions** are needed to support **healthy nutritional status** and prevent **obesity-related behaviors**.

Thank you

The development of an ecological momentary intervention to improve reward-related eating in adult women

- **Subject(s)**
  - Food, nutrition and diet
  - Innovative approaches in health information and service delivery
- **Relation to conference main theme**
  - Digital innovation and ethical technology use
- **Keywords**
  - **Reward-related eating**
  - **Ecological momentary intervention**
  - **Social cognitive theory**
  - **Behavior change techniques**
  - **Adult women**

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