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Applied nutritional investigation

Does stress compromise fruit and vegetable intake? A randomized controlled trial testing a model with planning as a mediator and stress as a moderator

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A B S T R A C T

Objective: Individuals experiencing higher stress levels tend to consume fewer fruits and vegetables compared to their less stressed counterparts. Thus, to promote fruit and vegetable (FV) consumption, action planning has been proven effective in translating behavioral intentions into actual dietary behaviors. *This study aims to evaluate a 7-day intervention designed to improve FV planning and intake, while also examining the role of stress.*
Methods: The trial employed a 3 (time: pretest, post-test, and follow-up) * 2 (group: intervention vs. control) between-participant factorial design. A total of 99 young Chinese adults (age = 23.84 years ± 4.63, 26 men) who had formed an explicit intention to consume more fruit and vegetables, participated in a 7-day online randomized controlled trial.
Results: The intervention successfully enhanced FV planning as well as FV intake. Furthermore, a moderated mediation model revealed that FV planning mediated the relationship between experimental conditions and FV intake, with stress moderating this mediation. Specifically, planning facilitated FV intake for individuals with low stress levels, while this effect was not observed for those with high stress levels.
Conclusion: These findings confirm the positive impact of the planning intervention on improving FV intake, particularly for individuals with low stress levels, and highlight stress as a barrier to health behavior change that warrants further attention in future studies.

Introduction

Fruits and vegetables (FV) are essential components of a healthy diet. The World Health Organization (WHO) recommends a daily intake of at least 400 g of fruit and vegetable (equivalent to approximately five fists in size; WHO, 2003). Embracing a habit of adequate FV intake can significantly promote overall health. Epidemiological studies and systematic reviews have indicated that insufficient intake of vegetables and fruits may elevate the risk of various health conditions, such as cancer, cardiovascular disease [1], diabetes, metabolic syndrome [2], chronic respiratory disease, intestinal disease, fractures, and cognitive impairment [3]. Regrettably, inadequate FV consumption continues to rank among the top five global dietary risk factors [4].

As China experiences rapid economic development, it also faces challenges to national health due to the prevalence of material wealth, leading to excessive consumption of high-fat and delicious foods while neglecting FV intake. A survey conducted on a large sample of Chinese adults (N = 170,847), revealed that only 53.2% met the WHO's-recommended levels of fruit and vegetable consumption [5]. In China, the consumption of fresh fruit is low, and most vegetables are consumed after being cooked, resulting in distinct FV intake patterns compared to Western countries [6]. Therefore, increasing the intake of FV is an important goal for global public health, including in China [5].

Adherence to dietary recommendations necessitates positive intentions and the development of self-regulatory skills and behaviors, such as creating a plan to translate dietary goals into

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action [7].The Health Action Process Approach (HAPA; [8]) suggests that planning plays a crucial mediating role in the relationship between intention and behavior. While many individuals acknowledge the importance of health behaviors and form dietary intentions, they often fail to engage in actual health behaviors. However, when individual strategically plan the “when,” “where,” and “how” of implementing a health behavior, the likelihood of successfully translating the intention into action significantly increases. Planning goes beyond mere intention; it encompasses specifying the context (timing and location) and outlining a sequence of actions (how, [8]). Specific contexts can automatically induce behaviors and sequences of actions; that is, detailed plans, can be more easily remembered, and therefore, thereby serving as predictors of health behaviors [9]. Although most existing studies have confirmed that planning interventions improve health behaviors [10], the precise mechanism by which these interventions operate remain poorly understood [11–13]. The relationship between planning and health behaviors involves complex processes, suggesting the contribution of additional factors. Further exploration of the mechanisms by which planning facilitates the implementation of health behaviors is needed to improve the effectiveness of interventions. Barriers and resources can have an impact on the implementation and maintenance of health behaviors [14,15]. For example, social support resources have a facilitative effect on healthy eating behaviors [16,17], whereas perceived barriers have a debilitating effect [14,15]. Most health behavior change studies have focused only on individual self-regulation (e.g., planning) and have less often considered both barriers and resources. In this study, stress is considered as one barrier in the volitional phase, where intentions need to be translated into actual behaviors. Empirical evidence suggests that individuals with higher levels of stress mostly consume more foods high in fat and sugar and fewer vegetables as compared to those with less stress [2,18]. A possible explanation for this, based on psychological resource theory [19], is that stress depletes individuals’ psychological resources, impairing the higher executive functions of self-regulation such as working memory and behavioral monitoring supported by the brain’s prefrontal lobe, and disrupting self-regulated cognitive processes [20,21]. Specifically, recurrent negative emotions during stress deplete self-management resources, which are important for controlling eating behaviors [22]. What is less known is how stress regulates the self-regulatory processes in the volitional phase. Specifically, the mechanism of how stress and planning may interact with healthy eating behaviors remains unclear.

This study uses an online randomized controlled approach to examine the effect of a dietary planning intervention on FV intake in a Chinese adult population. Based on the results of previous studies [23], Hypothesis 1 is proposed: the FV planning group will display higher FV planning and intake as compared to the control group. Moreover, this study explored a mediating model consisting of intervention manipulation, FV planning, and intake. Based on psychological resource theory [19], Hypothesis 2 proposes a moderating effect of perceived stress: stress may compromise the facilitating effect of FV planning on FV intake.

Methods

Participants

To recruit young adults for the study (mainly undergraduate students in continuing education and company employees) a combination of whole-group random sampling and social random sampling was used. Specifically, whole-group random sampling was used to randomly select participants from groups of students in continuing education programs, ensuring the representativeness of the student sample. Social random sampling involved recruiting company employees through random sampling methods on social platforms and within companies, ensuring the diversity and representativeness of the employee sample. For sample size calculations, the following procedures were applied. Previous studies on the effect of action planning on dietary change have reported a partial eta square of 0.18 [24]. Based on this effect size, we first transformed it to Cohen’s f (0.47) and selected the minimum Cohen’s f as the prior effect size to calculate the minimum required sample size. For the between-participant factorial design of a 3 (time: pretest, post-test, and follow-up) * 2 (group: intervention vs. control), with an alpha of .05, power of 0.80, and correlations among repeated measures of 0.5, we calculated the sample size as 48 using the G*Power software (Faul et al., 2009). Considering the attrition rate of daily diary methods, this study set the attrition rate at 40%. We will set 80 participants (calculated as 48 / [1 - 40%], accounting for a 40% expected dropout rate) as the minimum sample size for this study, with each experimental condition group having 40 participants.

Inclusion criteria: Selection of motivated participants. Considering that the purpose of this study was to explore the effect of an intervention on FV planning and FV intake, individuals should be in the postintentional stage of change (having formed an intention but without having planned actual FV intake). To assess whether participants were in the postintentional (volitional) stage of healthy eating, two questions were asked: “Do you plan to increase your intake of fruit and vegetable?” and “Do you have a detailed plan to increase your intake of fruit and vegetable (e.g., when and where you will allow yourself to eat more fruit and vegetable)?” If they answered “yes” to the first question and “no” to the second question; that is, they had the intention to eat more fruit and vegetable, but did not have a specific plan, they were in the postintentional (volitional) phase in which they still had to translate their intention into actual behaviors (e.g., by planning their diet).

A total of 757 questionnaires from 27 Chinese provinces were collected. Owing to the inclusion criteria, 142 young adults were recruited who had stated an intention to consume more fruit and vegetables. They were randomly divided into two groups: $n = 77$ in the FV intake planning group and $n = 65$ in the passive control group. More participants were intentionally assigned to the intervention group because prior experience indicated a higher withdrawal rate among participants from the intervention group in randomized controlled trials [25,26]. The randomization of participants was carried out using a computer-generated random number sequence. After confirming their eligibility, participants were assigned a unique identification number. These identification numbers were then input into a random number generator, which allocated participants to either the FV intake planning group or the passive control group.

After all the intervention and follow-up tasks were completed, the validity of questionnaire responses was verified by bogus test questions, and participants who completed the assessments at all time points were included in the final analysis. In the end, 99 valid cases were obtained. The Consolidated Standards of Reporting Trials (CONSORT; Schulz et al., 2010) diagram depicting participant flow through the study is shown in Figures 1-3.

Experimental procedure

Participants provided demographic information and completed the baseline questionnaire on day 1. Further, during days 1 to 7 (June 5 to 11, 2020), every evening from 20:00–23:00 hours,

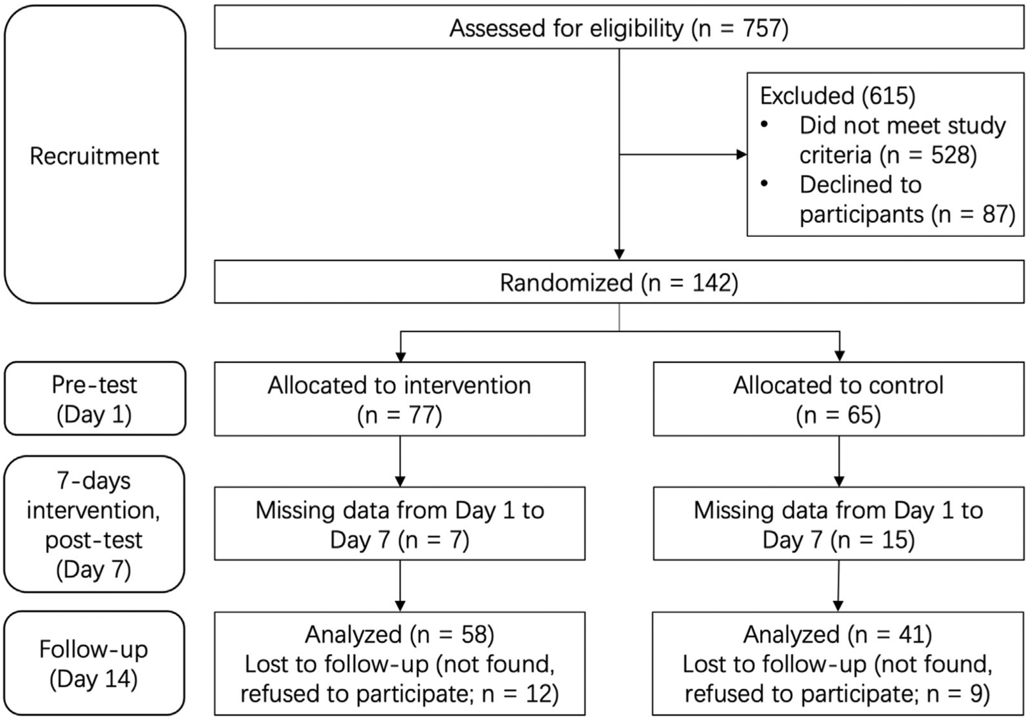

Fig. 1. Consolidated Standards of Reporting Trials (CONSORT) diagram depicting participant flow through the study.

participants in the intervention group answered questions related to the planning of FV intake, and they planned for the next day's FV intake. The passive control group received no treatment components. On day 14 (June 18, 2020), all participants completed a follow-up questionnaire about perceived stress and their FV intake during the week after the intervention.

Ethics approval and consent to participate

This study was conducted according to the guidelines of the Declaration of Helsinki, and has been approved by the Committee for Protecting Human and Animal Subjects at the School of Psychological and Cognitive Sciences in Peking University (the approval number is #2020-04-11). Before participating in the study, all participants in each study were informed of the project contents, risks and benefits, and could withdraw at any time. The informed consents were obtained from all participants.

Materials

Questionnaire

Stress. The Perceived Stress Scale (PSS, [27]): comprises 10 questions such as "How often do you get upset about unexpected things for the past one week?" Responses were made on a four-point scale from 1 "never" to 4 "always." The internal consistency was Cronbach's alpha = 0.90.

All other measures were adopted from Schwarzer [8], and for their Chinese versions, we referred to Zhou [24].

Fruit and vegetable intake: The healthy eating behavior scale consisted of two questions: "I eat about ____ servings of fruit per day" and "I eat about ____ servings of vegetables per day," with 0.5

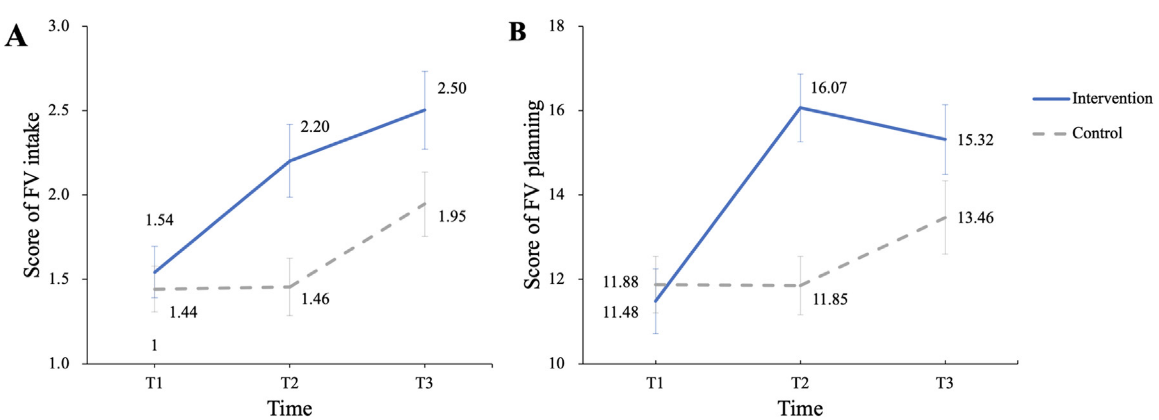

Fig. 2. Changes in FV intake (A) and planning (B) over three points in time. Notes: FV = fruit and vegetable; T1 = Time 1 (day 1), T2 = Time 2 (day 7), T3 = Time 3 (day 14); Error bar = ± 1 SE.

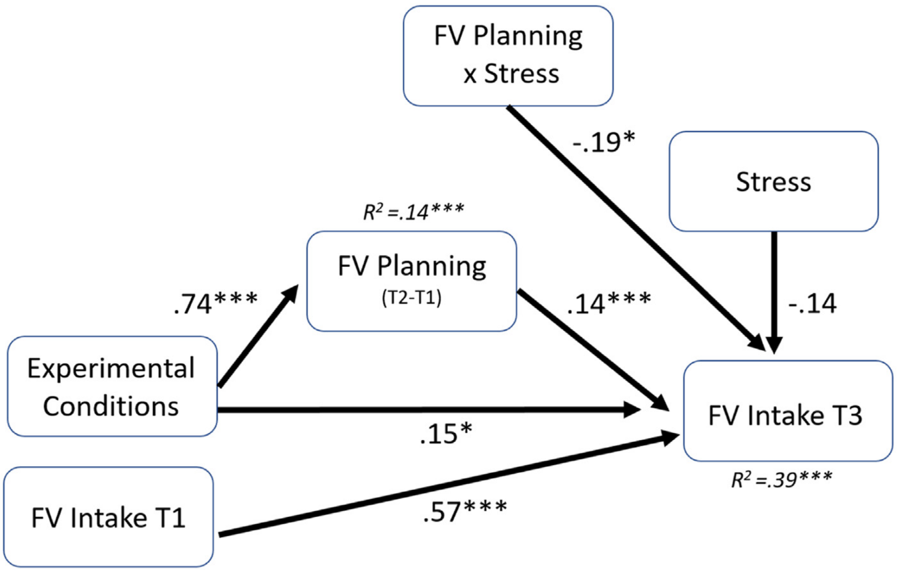

Fig. 3. The moderated mediation model. Notes: FV = fruit and vegetable, T1 = Time 1 (day 1), T2 = Time 2 (day 7), T3 = Time 3 (day 14); FV planning (T2-T1) was calculated by the change from T2 (day 7) to T1 (day 1); *$P < 0.05$, ***$P < 0.001$.

representing half a serving and 1 representing one serving. The internal consistency was Cronbach's alpha = 0.88 (T1), 0.82 (T2), and 0.88 (T3).

Fruit and vegetable planning: This scale included six items (please see the Supplementary File for details), such as "I have made plans of what a particular fruit or vegetable to eat." The scores of FV planning were calculated using the mean of these six items. The internal consistency was Cronbach's alpha = 0.91 (T1), 0.91 (T2), and 0.95 (T3).

Intervention material

Planning intervention material: Participants reported the specific time and the amount of fruits and vegetables they planned to consume on the next day, as well as possible difficulties and solutions to enact the dietary plan, as described below.

> *To better help you improve your eating habits, please plan your vegetable and fruit intake for tomorrow. If you set a time point to increase your fruit and vegetable intake, when would you choose to increase your fruit and vegetable intake tomorrow? (Multiple time points are allowed, separated by commas). If you set a location to increase your fruit and vegetable intake tomorrow, which location would you choose? (e.g., home, cafeteria (specify which window), a fast-food restaurant (specify the name of the restaurant), etc.; Multiple locations may be filled in, separated by commas). In the process of implementing the above healthy eating plan, what difficulties and obstacles might you encounter? (Please fill in more than 15 words). What do you do to keep yourself from increasing your fruit and vegetable intake when you encounter the above difficulties and obstacles? (Please fill in 15 words or more)*

Control group: No intervention content.

Statistical analysis

This study used SPSS (IBM, Armonk, NY, USA) 23.0 and its PROCESS Macro (Hayes, 2018) to analyze the data. The significance of differences was first tested using t-tests for baseline demographic variables and key variable scores. Then, the intervention effect was tested for significance using a multivariate analysis of covariance (MANCOVA). Bias-corrected percentile bootstrapping was also employed, with the expectation that planning would play a mediating role between the intervention and the FV intake at follow-up. Besides, Johnson–Neyman analysis was conducted using the *interactions* package (https://www.rdocumentation.org/packages/interactions/versions/1.1.5) of R software [28,29], which could identify the specific range of the moderation effect.

Results

Demographic and descriptive statistical results

First, we conducted a randomization check on the pretest results of demographics, daily stress level, and FV intake of the two groups. Table 1 showed participants' basic characteristics, Body Mass Index (BMI) scores, and BMI group [30] by intervention groups. The results showed that the differences between the pretest scores of the two groups on the demographic variables (p_{sex} = .103, p_{age} = .236, $p_{education\ level}$ = .488, and $p_{monthly\ income}$ = .137) and the key variables (p_{BMI} = .820, $p_{perceived\ stress}$ = .544, $p_{FV\ plan}$ = .697, and $p_{FV\ intake}$ = .616) were not significant. Besides, the level of BMI ($p_{FV\ planning}$ = .797, $p_{FV\ intake}$ = .160) and the interaction between BMI and group ($p_{FV\ planning}$ = .992, $p_{FV\ intake}$ = .290) had no effect on the FV planning and intake. The mean, the variance of the key variables, and the partial correlations among the key variables after controlling for demographic variables are shown in Table 2.

Changes in fruit and vegetable intake and planning at three measurement points in time

After controlling for demographic variables (sex, age, education level, and monthly income), a multivariate analysis of covariance (MANCOVA) was conducted on FV planning as well as for FV intake for experimental conditions at three points in time: before and after the intervention as well as at follow-up. The mean and SD of FV intake and FV planning for each group at each time point are shown in Table 3.

Table 1
Basic characteristics and BMI results by intervention groups

	Intervention (*N* = 58)	Control (*N* = 41)	Total (*N* = 99)
Age			
Mean (SD)	24.2 (4.92)	23.2 (3.53)	23.8 (4.41)
Median (Min, Max)	23.0 (18.0, 42.0)	22.0 (18.0, 39.0)	23.0 (18.0, 42.0)
BMI			
Mean (SD)	21.0 (2.91)	20.9 (2.45)	21.0 (2.72)
Median (Min, Max)	20.5 (16.5, 31.1)	20.7 (16.8, 26.7)	20.7 (16.5, 31.1)
BMI Group			
Underweight (≤18)	14 (24.1%)	8 (19.5%)	22 (22.2%)
Normal range (18.5–25)	39 (67.2%)	31 (75.6%)	70 (70.7%)
Overweight (25–30)	4 (6.9%)	2 (4.9%)	6 (6.1%)
Obese (≥30)	1 (1.7%)	0 (0%)	1 (1.0%)
Sex			
Female	46 (79.3%)	27 (65.9%)	73 (73.7%)
Male	12 (20.7%)	14 (34.1%)	26 (26.3%)
Employee			
Student	42 (72.4%)	33 (80.5%)	75 (75.8%)
Working full-time	16 (27.6%)	8 (19.5%)	24 (24.2%)
Education			
High school or lower	2 (3.4%)	0 (0%)	2 (2.0%)
Undergraduate	41 (70.7%)	29 (70.7%)	70 (70.7%)
Master degree or above	15 (25.9%)	12 (29.3%)	27 (27.3%)
Income per month			
Less than 3000	4 (6.9%)	4 (9.8%)	8 (8.1%)
3000–5000	8 (13.8%)	13 (31.7%)	21 (21.2%)
5000–10000	25 (43.1%)	11 (26.8%)	36 (36.4%)
10000–20000	16 (27.6%)	11 (26.8%)	27 (27.3%)
More than 20000	5 (8.6%)	2 (4.9%)	7 (7.1%)

Note. BMI = Body Mass Index.

Table 2
Descriptive results and partial correlations

	Variables	Mean	SD	1	2	3	4	5	6	7
1	Stress_T7	30.22	5.06	0.90						
2	FV Intake_T1	1.50	0.98	0.10	0.88					
3	FV Intake_T2	1.89	1.39	0.14	0.65***	0.82				
4	FV Intake_T3	2.27	1.48	−0.05	0.54***	0.61***	0.88			
5	FV Planning_T1	11.65	4.93	0.01	0.13	0.16	0.14	0.91		
6	FV Planning_T2	14.32	5.33	−0.23*	0.15	0.35***	0.37***	0.34**	0.91	
7	FV Planning_T3	14.55	5.76	−0.19	−0.02	0.19	0.25*	0.39***	0.79***	0.95

Notes. FV = Fruit and vegetable; T1 = Time 1 (day 1), T2 = Time 2 (day 7), T3 = Time 3 (day 14); the value on the diagonal is the internal consistency of Cronbach's alpha for the scale; *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Table 3
Intake and planning of fruit and vegetable at three points in time

	Time	T1 (pre)		T2 (post)		T3 (follow-up)		Cohen's d		
	Groups	Mean	SD	Mean	SD	Mean	SD	T1-T2	T1-T3	T2-T3
Fruit and vegetable Intake	Intervention	1.54	1.04	2.20	1.49	2.50	1.58	0.51	0.72	0.20
	Control	1.44	0.90	1.46	1.13	1.95	1.26	0.01	0.46	0.41
	Total	1.50	0.98	1.89	1.39	2.27	1.48	0.33	0.62	0.27
Fruit and vegetable Planning	Intervention	11.48	5.28	16.07	5.52	15.32	5.68	0.85	0.70	−0.13
	Control	11.88	4.45	11.85	4.56	13.46	5.78	−0.01	0.31	0.31
	Total	11.65	4.93	14.32	5.53	14.55	5.76	0.51	0.54	0.04

Fruit and vegetable intake

The results showed a main effect of group membership ($F_{(1, 87)} = 4.28$, $P = 0.041$, partial $\eta^2 = 0.04$) with a significantly higher total fruit and vegetable intake in the intervention group than in the control group (1.61 to 2.09 cups, respectively; Cohen's d = 0.97). However, the main effect of time on fruit and vegetable intake was not significant ($F_{(2, 87)} = 0.05$, $P = 0.948$, partial $\eta^2 = 0.00$).

The interaction effect of time by group on FV intake was significant ($F_{(2, 87)} = 4.02$, $P = 0.020$, partial $\eta^2 = 0.04$). The results of the simple effects analysis were as follows: for the intervention group, the differences in FV intake at the pretest, post-test, and follow-up were significant (T1–T2: 1.54 to 2.20, respectively; Cohen's d = 0.51, $P < 0.001$; T1–T3: 1.54 to 2.50, respectively; Cohen's d = 0.71, $p < .001$; T2–T3: 2.20 to 2.50, respectively; Cohen's d = 0.20, $P < 0.001$). Whereas for the control group, the differences between the pre- and post-tests were not significant (Cohen's d = 0.01, $P = 1.00$) but significant between the pretest and follow-up (Cohen's d = 0.46, $P = 0.029$) and the post-test and follow-up (Cohen's d = 0.41, $P = 0.022$).

Fruit and vegetable planning

The results showed a group's main effect for FV planning ($F_{(1, 87)}$ = 4.02, P = 0.048, partial η^2 = 0.04), with the intervention group scoring significantly higher on FV planning than the control group. The main effect of time on FV planning was not significant ($F_{(2, 87)}$ = 0.30, P = 0.685, partial η^2 = 0.00). A pairwise comparison revealed a significant increase in participants' FV planning compared to baseline at both the post-test (Cohen's d = 0.51, P = 0.001) and follow-up (Cohen's d = 0.54, $P < 0.001$), with no significant difference between FV planning at follow-up or post-test (Cohen's d = 0.04, P = 0.777).

There was a significant time by group interaction effect for the level of FV planning ($F_{(2, 87)}$ = 8.03, P = 0.001, partial η^2 = 0.08), and the results of the simple effects analysis were as follows: for the intervention group, planning differed significantly between the pretest and post-test (Cohen's d = 0.85, $P < 0.001$) and the pretest and follow-up (Cohen's d = 0.70, $P < 0.001$), but not between the post-test and follow-up (Cohen's d = -0.13, P = 0.338). For the control group, planning did not differ significantly between the pretest and post-test (Cohen's d = -0.01, P = 1.00); however, planning differed significantly between the pretest and follow-up (Cohen's d = 0.31, P = 0.232) and post-test and follow-up (Cohen's d = 0.31, P = 0.019).

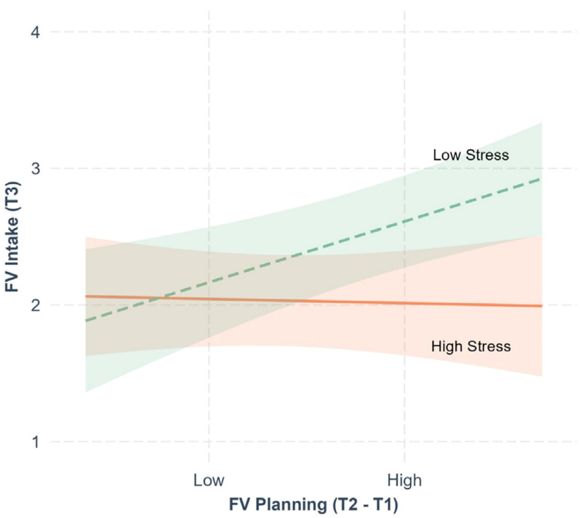

Fig. 4. Simple slope analysis: stress levels moderate the effect of FV planning (T2-T1) on FV intake (T3). Notes: FV = fruit and vegetable, FV planning (T2-T1) was calculated by the change from T2 (day 7) to T1 (day 1), high and low stress were created by splitting the sample with ±1 SD of stress scores measured at T2, curved lines indicate 95% confidence intervals.

Mediating effects with moderation: The mechanism of planning and stress in fruit and vegetable intake following a dietary intervention

The mediating role of planning in the effect of experimental conditions (intervention vs. control) on fruit and vegetable intake and the moderating role of chronic stress were examined after controlling for baseline FV intake. For the chronic stress score, the average of stress over seven days during the one-week intervention period was used for measurement); for the planning score, the change from day 1 to day 7 (day 7−day 1) was used; and for the fruit and vegetable intake, participants' score at follow-up (T3, day 14) was used.

Bias-corrected percentile bootstrapping (5,000 resamples) was employed to estimate the mediating effect of planning and the moderating effect of chronic stress (Figs. 4 and 5). The calculated predictive effect of planning on fruit and vegetable intake was significant at lower chronic stress levels (β = .37, P = 0.011, (95% CI [0.08, 0.59]) but did not reach significance at higher chronic stress levels (β = -.04, P = 0.755), (95% CI [-0.28, 0.20]). The mediating effect of planning was significant at lower levels of chronic stress (β = -.25, (95% CI [-0.49, -0.02]) but not at higher levels of chronic stress (β = .03, (95% CI [-0.26, 0.10]). Moreover, the index of moderated mediation was .14, (95% CI [0.01, 0.31]).

Furthermore, the Johnson−Neyman technique was used to investigate the moderation effect [31]. As shown in Figure 5, when the stress score was less than 30.42, the effect of FV planning (T2-T1) on FV intake (T3) was significantly positive, whereas when the stress score was greater than 30.42, the correlation between FV planning (T2-T1) and FV (T3) intake was nonsignificant.

Discussion

A dietary planning intervention has been developed and evaluated within a randomized controlled trial incorporating three

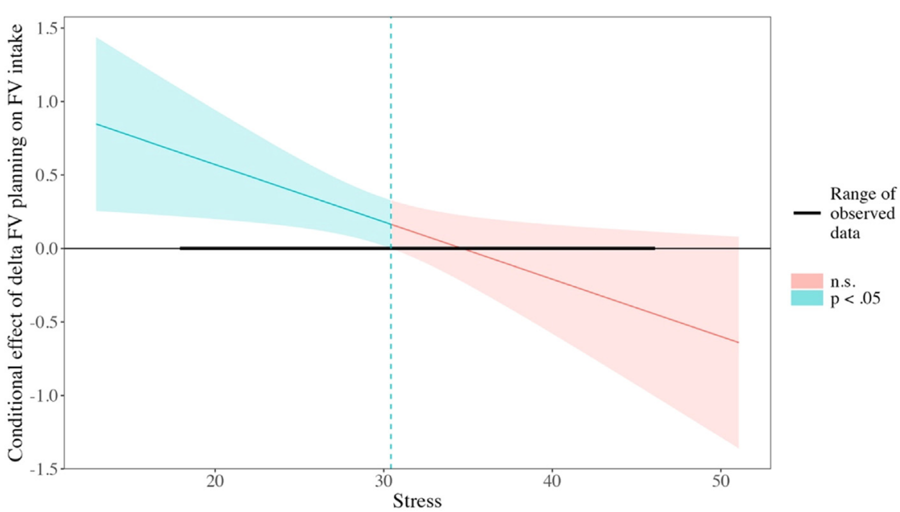

Fig. 5. Johnson−Neyman region of significance for the conditional effect of delta FV planning on FV intake. Notes: FV = fruit and vegetable, color bands depict 95% confidence intervals—red region indicate significant and blue nonsignificant conditional effects, P value was significant when stress = (18.00, 30.43), and was not significant when stress = (30.43, 46.00).

assessment points in time. This intervention contained a 7-day planning treatment to improve FV planning as well as FV intake. Further, this study explored the putative moderating role of chronic stress levels.

It was found that participants in the intervention group had higher FV planning and FV intake levels than did the control group at post-test and at follow-up. This is consistent with prior results [7,32].

One feature of this study is the continued treatment over a 7-day period. The online daily diary method compensates for the limitations of traditional interventions by capturing the extent that participants change their fruit and vegetable planning and intake, reducing retrospective bias and ensuring data accuracy [33]. When used as an intervention, the diary method is effective in increasing the intensity of the intervention, prompting participants to monitor and adjust the implementation of the FV plan and FV intake daily, and improving the effectiveness of the intervention.

A positive predictive effect of fruit and vegetable planning on fruit and vegetable intake was found in a Chinese population, which is consistent with previous results in a HAPA-related study [34]. Further, this study points to the role of chronic stress levels as a barrier when it comes to translating a dietary intention into actual behaviors. Stress hinders the positive effect of FV planning on FV intake. In the case of low perceived stress, the higher the fruit and vegetable planning, the higher the fruit and vegetable intake; however, in the case of high perceived stress, although the individual has formed an action plan, planning does not promote the final fruit and vegetable intake.

Numerous studies have identified the relationship between stress and health behaviors. Stress can affect health directly through autonomic and neuroendocrine responses or indirectly through health behavior changes [35–37]. This study validated the latter through a moderated mediation model, whereby stress indirectly affects individuals' healthy eating behaviors and physical and mental health by influencing the process between individuals' fruit and vegetable planning to fruit and vegetable intake.

The fruit and vegetable intervention designed in this study was effective in promoting fruit and vegetable eating behaviors in people with low chronic stress, which could reduce other health risks associated with inadequate FV intake. However, the mechanisms by which individuals adopt health behaviors in high- and low-stress states differ, making the investigation of how to facilitate the transition from developing a health plan to adopting health behaviors in high-stress individuals a focus for future research. Thus, future studies could further design experiments to explore whether interventions designed to alleviate individuals' stress could also promote their health behaviors, as well as the possible synergistic effects of stress and action-planning interventions. In addition to stress, future research could also consider additional hindering factors, such as an individuals' executive control function [38,39], to further promote healthy behaviors.

There are several limitations to this study. First, this study found a hindering effect of chronic stress in the relationship between planning and health behaviors; however, this finding was limited to FV intake under a healthy diet, and future studies could replicate this result for other dietary behaviors such as fat consumption, and snacking. Second, the results should be viewed as preliminary because the indicators of FV intake were self-reported, and the data may have been affected by self-consistency that inflated the observed correlations. Future studies could consider more objective behavioral indicators, such as having participants take pictures of the fruit and vegetable they consumed that day and weigh the amount of FV intake based on the photos. Third, the intervention effect was only measured seven days after the end of the intervention and at follow-up. Future studies could extend the follow-up to examine the long-term effects of healthy eating interventions. Moreover, daily real-time assessments could be analyzed in a more fine-grained matter, using multilevel methods. Fourth, the findings are limited to a sample of Chinese young adults.

In sum, this randomized controlled study used a daily intervention method to examine the effectiveness of a dietary planning program and to identify the role of chronic stress in compromising the behavioral change process from fruit and vegetable planning to fruit and vegetable intake.

Declaration of competing interest

The authors declare that they have no competing interests with the current study.

CRediT authorship contribution statement

Qianqian Ju: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing, Project administration, Validation. **Yiqun Gan:** Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing, Project administration. **Huini Peng:** Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. **Binghui Li:** Formal analysis, Writing – original draft, Writing – review & editing. **Shu Nie:** Conceptualization, Writing – original draft, Writing – review & editing. **Ralf Schwarzer:** Conceptualization, Validation, Writing – original draft, Writing – review & editing.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2024.112581.

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