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A staged integrated model informing the promotion of healthy dietary behaviors in adolescents: a prospective study

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Abstract

Background The promotion of healthy dietary behaviors in adolescence is critical, which have long-term implications for lifelong health. Integration is an important method for improving limited theories of dietary behavior change. The present study proposes an integrated model aimed at identifying the diverse determinants of healthy dietary behaviors in adolescents and assesses its stage-specific nature as the potential for effective interventions.

Methods A two-year prospective study was conducted in southwest China, involving a sample of 1990 adolescents (mean age: 15.06 years) from two randomly selected secondary schools. A total of 765 adolescents were exposed to the three-phase interventions while 1225 adolescents participated as the control group. The interventions aimed to promote healthy dietary behaviors in adolescents, which included health education sessions and health handbooks targeting specific constructs of the integrated model. The follow-up surveys after corresponding interventions were performed every six months. Self-reported frequency of healthy dietary behaviors, psychological constructs integrated from Health Action Process Approach, Health Belief Model, and Theory of Planned Behavior, as well as anxiety symptoms were measured.

Results Within structural equation modeling controlling for past behavior, the integrated model accounted for 61.7% variance of behavioral intentions and 19.1% variance of healthy dietary behaviors, and showed discontinuity patterns across behavior change phases. The pivotal constructs included outcome expectancies, perceived severity, subjective norms, action self-efficacy, behavioral intentions, action planning, and maintenance self-efficacy. Anxiety was an emotional barrier in the dietary behavior modification (β = -0.113, $P < .001$). Interventions within the staged integrated model, led to increased adoption of healthy dietary behaviors in intervention group compared to control group (33.40% vs. 25.70%, $P < .05$), indicating certain effectiveness, particularly in targeting action self-efficacy (stronger direct effects on behavioral intentions and maintenance self-efficacy, $\beta = 0.489$ to 0.704, $P < .001$).

Conclusions The staged integrated model provides a detailed understanding of the determinants of healthy dietary behaviors in adolescence, highlighting anxiety as an emotional barrier that impedes positive cognition and healthy dietary behaviors. It provides valuable guidance for future interventions targeting specific constructs across behavior change phases, with particular emphasis on enhancing action self-efficacy.

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Keywords Adolescents, Diet, Behavior change, Integrated theory, Stage model, Health action process approach

Background

The promotion of healthy dietary behaviors among adolescents is essential for establishing a foundation for lifelong health [1, 2]. Targeting key behaviors such as increased consumption of fruits and vegetables, regular breakfast intake, and reduced snacking potentially prevents overweight, obesity, and diet-related chronic diseases [3–5].

Numerous social psychology theories, such as the Health Belief Model (HBM) [6, 7], Theory of Planned Behavior (TPB) [8, 9], and Health Action Process Approach (HAPA) [10, 11], have been extensively employed to predict and intervene in the realm of healthy dietary behaviors among adolescents. Nonetheless, improving dietary behavior is an intricate process influenced by various cognitive, emotional, and social factors [10]. The individual theories have their own boundary conditions and specific concentrates, rendering no single theory unequivocally applicable to dietary behavior change in adolescents. Integrating multiple theories can provide a more comprehensive explanation and guide interventions [12]. However, there remains a relative dearth of integrated theories specifically targeting the full spectrum of healthy dietary behaviors among adolescents, necessitating further exploration to address this research gap.

The utility-based approach is one integration method that eliminates redundant constructs and combine variables and relationships from multiple existing theories to form a novel theoretical model [12]. In previous studies [13, 14], this integration method has been applied to develop models that explain or predict dietary behaviors. Given HAPA' s effectiveness in bridging the intention-behavior gap [15], it can serve as a framework for integrating theories. The HAPA model posits two processes of behavior change: a motivational process ending with intention and a volitional process culminating in behavioral performance. It shows stage-specific nature with distinct behavior change phases, such as nonintenders, intenders, and actors, enabling targeted interventions [10]. Further subdividing the volitional process may identify different phases, such as "planners" distinguishing intenders without execution plans from those intending to act. However, there is a research gap in current extended HAPA models regarding the retention of stage-specific nature and the investigation of transitions between behavior change phases.

To fill the aforementioned gaps, some adjustments for HAPA are necessary. Within the original HAPA framework [10], the motivational constructs such as outcome expectancies, risk perception, and action self-efficacy influence behavioral intentions which indirectly affect behavior through one volitional construct of planning, while the other volitional constructs like maintenance self-efficacy and recovery self-efficacy directly influence the behavior. Action self-efficacy has an impact on maintenance self-efficacy. Barriers and/or resources also play a role throughout the processes. However, it may be appropriate to replace risk perception with perceived severity from HBM for adolescents who do not perceive direct disease risk [12] and omit recovery self-efficacy which reveals minimal effects [16]. And it is paramount to supplement the HAPA model across various aspects. Specifically, in terms of cognitive factors, perceived behavior control from the TPB [8], which emphasizes the ease of action and control over anticipated conditions, can link with intentions and behavior, and correlate with action self-efficacy [17]. Moreover, current extended HAPA models inadequately integrate emotional factors, particularly anxiety, which is commonly observed among children and adolescents [18]. Anxiety potentially acts as a "barrier" in the HAPA model, influencing intentions, behaviors, action self-efficacy and the related perceived behavior control [19]. Additionally, HAPA primarily emphasizes individual self-regulation, with limited consideration for direct social influences on intention and behavior. The HBM's cues to action and the TPB's subjective norms can be incorporated to address this limitation. Cues to action are external environmental prompts that stimulate behavior and trigger the correlation between perceived severity and outcome expectancies (similar to perceived benefits) [6, 10]. And subjective norm reflects perceived social norms which may be the strongest predictor in adolescents [20], impacting intentions and self-efficacy [21]. Moreover, cues to action and subjective norms are proposed as externally perceived factors with interconnected effects [21]. Last but not least, including past dietary behavior as an additional predictor can test the sufficiency of the integrated model, indicating the influence of unconscious processes [22]. In addition, to support the integrated model's proposition, further empirical evidence is necessary to confirm discontinuity between phases and the effectiveness of tailored interventions for subgroups, validating the model's superiority [10].

Therefore, the aim of the present study is to propose an integrated model (Fig. 1) to identify diverse determinants that influence healthy dietary behaviors in adolescents, and to provide insights for the promotion of healthy dietary behaviors within this population. More specifically, this study tests the following three hypotheses: First, it is hypothesized that motivational and volitional

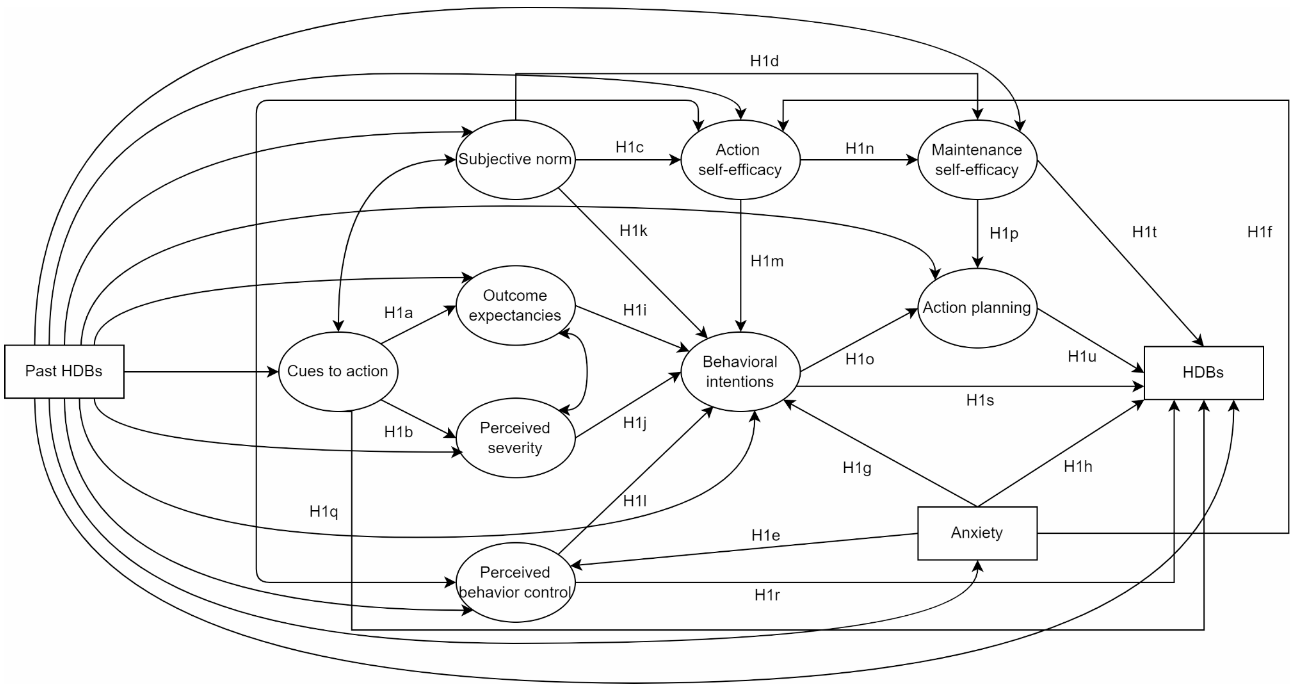

Fig. 1 The proposed integrated model
Note. Figure 1 illustrates the direct and correlated pathsillustrates the direct and correlated paths in the proposed integrated model. The proposed paths in hypothesis H1 were provided with corresponding path names next to the arrows (for example, "H1a" refers to the direct path from cues to action to outcome expectancies). The integrated model was adjusted by past healthy dietary behaviors. The rectangular and elliptical shapes represent the latent and manifest variables, respectively, within the framework of structural equation modeling. Abbreviation: HDBs, healthy dietary behaviors

factors interact to shape healthy dietary behaviors in the integrated model, with behavioral intentions serving as the central construct while anxiety being highlighted as an important emotional factor (H1). Second, it is further surmised that there will be discontinuity patterns observed between phases of dietary behavior change in the integrated model (H2). Finally, it is anticipated that the integrated model will demonstrate practical effectiveness in promoting the adoption of healthy dietary behaviors among adolescents (H3).

Methods

Participants and data collection

A two-year prospective research was conducted from October 2015 to October 2017 in Zizhong County, Sichuan Province, China. Zizhong County was chosen as the research site due to its representative socioeconomic level in rural areas of Sichuan Province. Two schools were randomly chosen from 17 secondary schools in the county. To ensure the feasibility of the follow-up study, baseline surveys were conducted with lower-grade students from both middle and high schools, with all Grade seven and Grade ten students from these two schools participating at baseline. Detailed study design can be found in a previous study [23].

Data collection was carried out through self-administered questionnaires. Surveys were conducted every semester for a total of five surveys over the research. The data used in this study were obtained from the first (time 1, April 2016), second (time 2, October 2016), and third (time 3, April 2017) follow-up surveys. Initially, the valid sample size was 2505 participants at time 1, but due to unforeseen circumstances, 277 (11.1%) participants were lost at time 2, and 238 (9.5%) were lost at time 3. Consequently, the analytical subsample for this study comprised 1990 eligible participants, with an average age of 15.06 years (standard deviation, *SD*: 1.50; *Range*: 11–19 at time 1). Among these participants, 881 (44.3%) were boys, and 1109 (55.7%) were girls.

Intervention components and procedures

Healthy dietary behavior change interventions were implemented targeting participants from School B (intervention group, $n=765$, 38.4%), while participants from School A ($n=1225$, 61.6%) served as the control group for comparison. The regular school health education curriculum remained unchanged for both the intervention and control groups. The interventions were conducted prior to each follow-up survey, which primarily employed health education sessions and health handbooks as the main methods.

It should be noted that the interventions targeted different variables of the proposed integrated model during various phases. The phase-one intervention aimed to cultivate intentions to adopt healthy dietary behaviors. It focused on enhancing participants' awareness, action self-efficacy and self-control over healthy dietary behaviors with support from friends, teachers, and parents. Building upon the initial phase, the phase-two intervention included guidance in developing and maintaining healthy eating plans, which aimed to translate the intentions into actual behaviors. Lastly, significant reinforcement and deepening of the content covered in the previous phases occurred during the phase-three intervention. This phase aimed to address any remaining barriers or challenges identified during the previous intervention. Detailed intervention protocols can be found in the Table 1.

All intervention measures were led by researchers specialized in health education and public health. Prior to conducting the interventions, we provided the researchers with uniform and rigorous training to ensure that each researcher had a clear understanding of the purpose and significance of the study. Furthermore, each researcher delivered a trial presentation in accordance with standardized courseware, and it was ensured that every researcher maintained consistency in the content and procedures of interventions. During health education sessions, each researcher actively engaged with students and patiently answered their questions. Upon completion of the sessions, the researchers ensured that all students received the health handbooks. After the interventions, participants were provided with learning materials such as pens and notebooks as rewards. We have provided a research flowchart in the Additional file 1: Figure S1, which includes the framework for the survey and intervention actions.

Table 1 The detailed intervention protocols

Interventions	Involved constructs	Methods	Implementation and contents
The phase-one intervention (October 2015 - March 2016)	Perceived severity Outcome expectancies Cues to action Subjective norm Perceived behavior control Action self-efficacy	Health education sessions	Implementation: Health education sessions were conducted in the classrooms by trained researchers who specialized in health education. Each session lasted for 45 min as part of the intervention, and was delivered through a combination of verbal communication, visual aids such as pictures and videos, and scenario simulations. The courseware used in the intervention was also shared with school teachers, who reviewed the intervention contents during daily class meetings with the participants.
			Contents: The main contents of the intervention comprised introducing healthy dietary behaviors, highlighting the adverse effects of a high-calorie diet, emphasizing the benefits of a nutritious diet, and sharing specific stories of success or failure.
		Health handbooks	Implementation: The handbooks were uniformly produced by the research team and distributed to all participants after the health education sessions. Participants were encouraged to share the handbooks with their families or friends.
			Contents: The contents focused on healthy dietary behaviors, including the demonstration of nutritious food choices, the harmful effects of a high-calorie diet, and the benefits of a balanced diet.
The phase-two intervention (April 2016 - September 2016)	Action planning Maintenance self-efficacy	Health education sessions	Implementation: The implementation method remained consistent with the initial intervention.
			Contents: The main focus was on assisting participants in translating their intentions into actual behaviors through effective planning. This included discussions on the duration of the plan, the strategies for plan implementation, and the introduction of specific cases (both successful and failed) to analyze the underlying reasons for their outcomes.
		Guidance on plan formulation	Implementation: Following the health education sessions, individualized face-to-face guidance was provided to the participants by trained researchers.
			Contents: The guidance covered various aspects, such as clarifying the objectives of the plan, determining the implementation methods, establishing a timeframe, anticipating potential obstacles, and devising the solutions.
The phase-three intervention (October 2016 - March 2017)	Action planning Maintenance self-efficacy healthy dietary behaviors	Health education sessions	Implementation: The implementation method remained consistent with the initial intervention.
			Contents: The sessions reinforced and deepened the content of the previous intervention to address any remaining barriers or challenges.

Measures

Healthy dietary behaviors

Healthy dietary behaviors were self-reported at time 1 (past HDBs) and time 3 (HDBs), assessed through a six-item questionnaire based on existing literature [13] and Chinese adolescent health-related behavior inventory [24]. This evaluation encompassed two domains: nutritional diet (consumptions of breakfast, fruits, and vegetables) and high-calorie diet (consumptions of carbonate beverages, deep-fried foods, and snacks). Participants rated their dietary behavior frequency over the preceding six months for past HDBs and one week for HDBs. For instance, the frequency of breakfast consumption as part of HDBs was evaluated using the item: "In the past week, how often did you consume breakfast?" These items implemented a five-point Likert scale ranging from *never* (0) to *everyday* (4). Items for high-calorie diet were reverse-scored. Both measures of past HDBs and HDBs demonstrated satisfactory internal consistency based on the dimensionality (Cronbach's α: 0.547 to 0.710) [25].

Psychological constructs

Cues to action, outcome expectancies, perceived severity, subjective norm, perceived behavior control, action self-efficacy and behavioral intentions were measured at time (1) Maintenance self-efficacy and action planning were assessed at time (2) Constructs and their corresponding items were derived from relevant literature [6, 8, 10], with modifications made to incorporate specific dietary behaviors and Chinese cultural considerations. A multi-item measurement approach was employed, utilizing Likert scales ranging from *not at all true* (1) to e*xactly true* (6) for most psychological constructs, except for action self-efficacy which used a four-point scale ranging from *strongly disagree* (1) to *strongly agree* (4). This approach ensured acceptable reliabilities (Cronbach's $\alpha > 0.6$) [26] and validities (convergent validity and discriminant validity) for all constructs. Additional file 2: Table S1 and Table S2 provides a detailed description and the psychometric properties.

Anxiety

Anxiety symptoms were examined by Zung Self-Rating Anxiety Scale [27], which has found extensive application in researches involving adolescents [28, 29]. The SAS comprises 20 items, with maximum score of 80. Higher scores indicate increased levels of anxiety. Participants rated the impact of each item on themselves over the past week using a four-point Likert scale, ranging from *none or a little of the time* (1) to *most or all of the time* (4). Positively worded items (5, 9, 13, 17, and 19) were reverse-scored. The Cronbach' α in this study was 0.811, indicating a satisfactory internal consistency [30].

Data analysis

The preliminary analyses included multivariate analysis of variance (MANOVA) to examine attrition, *Mean* (*SD*) statistics to assess the distribution of psychological constructs, and partial correlations to explore the associations between these constructs while controlling for past HDBs.

To test the relationships posited in the proposed integrated model (H1), structural equation modeling (SEM) was conducted within a robust framework, employing robust maximum likelihood estimation and bootstrapped resampling with 5000 resamples. This approach was adopted due to the departure of the data from multivariate normality, as indicated by Mardia's Index value of 373.465, which exceeds the critical value of 163.680 [31]. Direct and indirect effects, along with their corresponding 95% confidence intervals (95% *CI*), were calculated. Various indices were employed to assess the goodness of model fit, including the Chi-square statistics divided by the degrees of freedom (χ^2/df), the root mean square error of approximation (*RMSEA*), the comparative fit index (*CFI*), the goodness-of-fit index (*GFI*), the Tucker-Lewis index (*TLI*), and the normed fit index (*NFI*). In particular, $\chi^2/df < 5$, $RMSEA < 0.05$, and *CFI*, *GFI*, *TLI*, and *NFI* all > 0.9 are considered indicative of a good fit [32].

Furthermore, to investigate the discontinuity patterns of the model (H2), post hoc and polynomial analyses were carried out on the model variables among individuals with diverse phases of healthy dietary behavior change [33]. Error bar and trend line plots were created to visually depict the changing trends, thereby enabling the identification of key variables driving behavior phase transitions.

In addition, to elucidate the intervention's effectiveness (H3), a multi-group analysis employing SEM was conducted across the control group and the intervention group, examining the invariance of the integrated model and comparing the differences in paths between the two groups. The distribution differences of participants across different behavior change phases between the two groups were also examined.

The general analyses were conducted using SPSS 26.0 (IBM; Armonk, USA), while SEM analyses were performed using AMOS 26.0 (IBM; Armonk, USA). And the plots were created by R 4.3.2 (University of Okalan; Okalan, New Zealand). The level of statistical significance was set at 0.05 (two-sided).

Results

Descriptive analysis

We found no statistically significant difference in psychological variables and past HBDs between participants who provided complete data at all time-points and those who did not (Wilk's Lambda = 0.992, F(1900) = 1.452,

P=.143). Additionally, missing data on the measured variables were less than 5%. Descriptive statistics and partial correlations among all the involved variables are reported in Table 2.

Table 2 Descriptive statistics and partial correlations of model variables

Constructs	*Mean (SD)*	Partial correlations										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1. Cues to action	3.71 (1.39)	1.000										
2. Outcome expectancies	4.84 (0.97)	0.138	1.000									
3. Perceived severity	4.32 (1.14)	0.338	0.327	1.000								
4. Subjective norm	4.43 (1.01)	0.241	0.367	0.286	1.000							
5. Perceived behavior control	4.29 (0.96)	0.095	0.307	0.171	0.336	1.000						
6. Behavioral intentions	4.58 (1.05)	0.137	0.385	0.246	0.311	0.449	1.000					
7. Action self-efficacy	2.86 (0.50)	0.084	0.273	0.152	0.268	0.386	0.521	1.000				
8. Maintenance self-efficacy	3.68 (1.20)	0.134	0.117	0.104	0.208	0.217	0.214	0.295	1.000			
9. Action planning	3.81 (1.26)	0.080	0.150	0.111	0.178	0.245	0.274	0.338	0.453	1.000		
10. Anxiety	1.91 (0.41)	0.054	-0.200	-0.052	-0.070	-0.227	-0.229	-0.172	-0.066	-0.057	1.000	
11. HDBs	2.89 (0.60)	-0.003[a]	0.107	0.115	0.099	0.153	0.225	0.218	0.116	0.219	-0.130	1.000
12. Past HDBs	2.86 (0.58)	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*

Note. Abbreviations: HDBs, healthy dietary behaviors; *SD*, standard deviation. The partial correlations were adjusted for past healthy dietary behaviors, and all the correlations are statistically significant for P<.05 except for the value with [a]

Testing relationships posited in the proposed integrated model

When fitting the proposed model, we allowed the covariances between four pairwise variables based on modification indices and professional expertise (Table 3). The final model (Fig. 2) demonstrated good fit indices: χ^2/df=4.484, GFI=0.936, NFI=0.925, TLI=0.932, CFI=0.941, $RMSEA$=0.042.

As shown in Table 3, most motivational constructs had statistically significant direct effects on behavioral intentions, while cues to action (β=0.023, 95% CI=0.012 to 0.038) and subjective norm (0.153, 0.111 to 0.201) had indirect effects on behavioral intentions. On the other hand, only behavioral intentions (0.183, 0.115 to 0.253) and action planning (0.152, 0.091 to 0.211) directly affected HDBs, while most constructs had statistically significant indirect effects on HDBs, with motivational constructs exhibiting the largest effect mediated by behavioral intentions (0.191, 0.118 to 0.266).

Particularly, anxiety had statistically significant negative direct effects on perceived behavior control (-0.201, -0.248 to -0.152) and action self-efficacy (-0.170, -0.229 to -0.113). Meanwhile, anxiety directly affected behavioral intentions (-0.065, -0.111 to -0.017) and HDBs (-0.065, -0.109 to -0.022), with a larger indirect effect on behavioral intentions (-0.130, -0.171 to -0.092). Moreover, the impact of past HDBs was notable on action self-efficacy (0.279, 0.228 to 0.329) and HDBs (0.237, 0.188 to 0.285).

Overall the model accounted for 61.7% variance of behavioral intentions and 19.1% variance of healthy dietary behaviors, supporting our first hypothesis (H1). Specially, action self-efficacy had largest total effect on behavioral intentions (0.564, 0.474 to 0.660), while past HDBs had largest total effect on HDBs (0.332, 0.286 to 0.379). However, cues to action and perceived behavior control did not have a significant impact on HDBs. Please refer to the Additional file 3: Table S3 for additional results.

The discontinuity patterns of the integrated model

To account for the influence of past behavior, we restricted our classification to those (n=1298) with past HDBs values below the cutoff value of 3.17 (73rd percentile) [34]. Then, among them, with similar cutoff rule (73rd percentile), individuals with HBDs values equal to or above 3.17 were categorized as "Actors", while those below this threshold but with action planning values equal to or exceeding 4.67 were classified as "Planners". For the remaining individuals, those with behavioral intentions values equal to or above 5.00 were designated as "Intenders", with the others categorized as "Nonintenders".

Post hoc and polynomial analyses (Table 4) revealed differences in variable distributions without consistent increments or decrements across phases, exhibiting quadratic or cubic trends for considering it as a real stage model [33]. Error bar and trend line plots (Fig. 3) visually illustrated the discontinuity patterns of model variables, suggesting all variables' potential to facilitate the transition of behavior change phases. The above results provide evidence supporting the second hypothesis (H2).

The effectiveness of phased interventions

The nested models with different parameter constraints were compared across the control group and intervention group to test the invariance of the staged integrated model [31]. As presented in Additional file 4: Table S4 all nested models exhibited good fit, and the integrated model was stable across the control and intervention groups according to the change values of model fit indices [35, 36].

Effectiveness of interventions was assessed by comparing parameters between the control and intervention groups using critical ratios (C.R.) for differences. Results in Table 5 showed that the predicted mechanisms of change specified in the integrated model were largely supported in both groups. Specially, more than half of the direct effects were greater in the intervention group, with two paths demonstrating statistically significant disparities: action self-efficacy to behavioral intentions (C.R. = 2.832, $P<.01$) and action self-efficacy to maintenance self-efficacy (C.R. = 3.459, $P<.001$). The intervention group had stronger direct effects of action self-efficacy on behavioral intentions (0.704, 0.559 to 0.881) and maintenance self-efficacy (0.489, 0.389 to 0.582). Moreover, a significant difference in distribution was observed in the behavior change phases between the control and intervention groups, controlling for past behaviors ($n=1298$, $\chi^2(3)=9.435$, $P=.024$). The intervention group had a higher proportion of Actors (33.40%) compared to the control group (25.70%) (Bonferroni correction for multiple comparisons, $P<.05$), suporting the third hypothesis (H3).

Discussion

Rooted in the HAPA framework and incorporating the complementary constructs of TPB and HBM, we has developed a staged integrated model to delineate the extensive determinants that influences healthy dietary behaviors during adolescence across different behavior change phases. Grounded in this staged integrated framework, a one-year three-phase intervention was conducted in a school setting, showing promise for guiding targeted interventions.

Our findings highlight the significant role of motivational factors which explained a substantial portion of the variance (61.7%) in behavioral intentions, and also underscore the detrimental impact of anxiety on the process of dietary behavior modification in adolescents, supporting the hypothesis H1. Specially, this study supported indirect effects of subjective norm on behavioral intentions mediated by action self-efficacy. This aligns with the previous research suggesting that social norms, particularly from similar peers, can increase self-efficacy for a perception of personal control over the behavior [21]. It's worth noting that action self-efficacy was highlighted as the most important predictor of behavioral intentions, consistent with existing analyses [16]. Behavioral intentions directly influenced behaviors or were indirectly mediated by action planning, consistent with the expanded application in adolescent dietary behaviors [13]. Surprisingly, while perceived behavior control and cues to action exerted an impact on behavioral intention, they did not significantly affect healthy dietary behaviors. This finding contradicts initial assumptions but has been indicated in other behavior change studies [37, 38]. This could be attributed to adolescents' insufficient intention with limited autonomy in food choices [39]. Acknowledging this boundary condition is needed when applying this two constructs to adolescents' dietary behavior change. This study also considered the role of emotions in dietary behavior, which has been overlooked in the diet-related theoretical framework. Negative emotions, such as anxiety, may serve as barriers that impedes positive cognition and healthy dietary behaviors, due to the fact that adolescents may use unhealthy food as a coping mechanism for regulating their emotions, which could be in the development of emotional eating behavior [40, 41].

This study examined the discontinuity patterns of the integrated model, providing empirical evidence that supports its characterization as a real stage model, thus validating hypothesis H2. The stage model offers valuable guidance for the design of behavioral intervention programs, an approach that has been applied in previous research [10, 42]. In this study, adolescents were categorized into distinct phases of dietary behavior change based on levels of intention, planning, and actual behavior. And all determinants across different phases had the potential to facilitate the transition of behavior change phases. These findings suggested that interventions could be effectively tailored to target individuals at various phases—nonintenders, intenders, planners, or actors—by addressing the specific determinants relevant to each phase. This tailored approach, catering to individual needs, could enhance intervention effectiveness while maintaining cost efficiency.

Table 3 Standardized coefficients of path effects in the final integrated model

Paths		*β*	*SE*	95% *CI*	*P*
Direct effects					
H1a:	Cues to action→ Outcome expectancies	0.125	0.025	(0.076, 0.176)	< 0.001
H1b:	Cues to action→ Perceived severity	0.403	0.028	(0.346, 0.458)	< 0.001
H1c:	Subjective norm→ Action self-efficacy	0.272	0.032	(0.210, 0.332)	< 0.001
H1d:	Subjective norm→ Maintenance self-efficacy	0.079	0.030	(0.021, 0.138)	0.008
H1e:	Anxiety→ Perceived behavior control	-0.201	0.025	(-0.248, -0.152)	< 0.001
H1f:	Anxiety→ Action self-efficacy	-0.170	0.030	(-0.229, -0.113)	< 0.001
H1g:	Anxiety→ Behavioral intentions	-0.065	0.024	(-0.111, -0.017)	0.006
H1h:	Anxiety→ HDBs	-0.065	0.022	(-0.109, -0.022)	0.004
H1i:	Outcome expectancies→ Behavioral intentions	0.187	0.036	(0.116, 0.259)	< 0.001
H1j:	Perceived severity→ Behavioral intentions	0.106	0.032	(0.042, 0.169)	< 0.001
H1k:	Subjective norm→ Behavioral intentions	0.000	0.029	(-0.058, 0.059)	0.961
H1l:	Perceived behavior control→ Behavioral intentions	0.167	0.037	(0.093, 0.239)	< 0.001
H1m:	Action self-efficacy→ Behavioral intentions	0.564	0.047	(0.474, 0.660)	< 0.001
H1n:	Action self-efficacy→ Maintenance self-efficacy	0.370	0.034	(0.301, 0.435)	< 0.001
H1o:	Behavioral intentions→ Action planning	0.233	0.027	(0.180, 0.289)	< 0.001
H1p:	Maintenance self-efficacy→ Action planning	0.460	0.027	(0.405, 0.512)	< 0.001
H1q:	Cues to action→ HDBs	-0.038	0.022	(-0.081, 0.006)	0.085
H1r:	Perceived behavior control→ HDBs	0.010	0.029	(-0.047, 0.065)	0.758
H1s:	Behavioral intentions→ HDBs	0.183	0.035	(0.115, 0.253)	< 0.001
H1t:	Maintenance self-efficacy→ HDBs	-0.012	0.028	(-0.067, 0.042)	0.677
H1u:	Action planning→ HDBs	0.152	0.031	(0.091, 0.211)	< 0.001
Direct effects: past behavior					
	Past HDBs→ Cues to action	0.024	0.024	(-0.023, 0.070)	0.331
	Past HDBs→ Outcome expectancies	0.122	0.023	(0.076, 0.170)	< 0.001
	Past HDBs→ Perceived severity	0.122	0.024	(0.075, 0.169)	< 0.001
	Past HDBs→ Subjective norm	0.088	0.026	(0.039, 0.139)	0.001
	Past HDBs→ Perceived behavior control	0.152	0.023	(0.109, 0.198)	< 0.001
	Past HDBs→ Action self-efficacy	0.279	0.026	(0.228, 0.329)	< 0.001
	Past HDBs→ Anxiety	-0.156	0.022	(0.200, -0.112)	< 0.001
	Past HDBs→ Behavioral intentions	0.032	0.025	(-0.017, 0.081)	0.207
	Past HDBs→ Maintenance self-efficacy	0.023	0.024	(-0.024, 0.069)	0.352
	Past HDBs→ Action planning	0.072	0.024	(0.025, 0.120)	0.004
	Past HDBs→ HDBs	0.237	0.025	(0.188, 0.285)	< 0.001

Table 3 (continued)

Paths		*β*	*SE*	95% *CI*	*P*
Correlations					
	Outcome expectancies ↔ Perceived severity	0.351	0.035	(0.282, 0.419)	< 0.001
	Subjective norm ↔ Cues to action	0.220	0.027	(0.168, 0.272)	< 0.001
	Perceived behavior control ↔ Action self-efficacy	0.445	0.036	(0.373, 0.516)	< 0.001
	Subjective norm ↔ Perceived behavior control	0.313	0.030	(0.251, 0.372)	< 0.001
	Subjective norm ↔ Outcome expectancies	0.383	0.028	(0.327, 0.437)	< 0.001
	Subjective norm ↔ Perceived severity	0.223	0.032	(0.160, 0.287)	< 0.001
	Outcome expectancies ↔ Perceived behavior control	0.209	0.030	(0.148, 0.267)	< 0.001
Indirect effects					
Cues to action→ Outcome expectancies→ Behavioral intentions		0.023	0.007	(0.012, 0.038)	< 0.001
Cues to action→ Perceived severity→ Behavioral intentions		-0.015	0.009	(-0.033, 0.002)	0.085
Subjective norm→ Action self-efficacy→ Behavioral intentions		0.153	0.023	(0.111, 0.201)	< 0.001
Anxiety→ Motivational constructs→ Behavioral intentions		-0.130	0.020	(-0.171, -0.092)	< 0.001
Motivational constructs→ Behavioral intentions→ Volitional constructs→ HDBs		0.037	0.009	(0.020, 0.056)	< 0.001
Motivational constructs→ Behavioral intentions→ HDBs		0.191	0.037	(0.118, 0.266)	< 0.001
Motivational constructs→ Volitional constructs→ HDBs		0.032	0.014	(0.004, 0.060)	0.018
Anxiety→ Motivational constructs→ Behavioral intentions→ Action planning→ HDBs		-0.005	0.001	(-0.008, -0.002)	< 0.001
Anxiety→ Motivational constructs→ Behavioral intentions→ HDBs		-0.024	0.006	(-0.037, -0.013)	< 0.001
Anxiety→ Motivational constructs→ Volitional constructs→ HDBs		-0.004	0.002	(-0.007, 0.000)	0.018
Anxiety→ Behavioral intentions→ Action planning→ HDBs		-0.002	0.001	(-0.004, -0.001)	0.006
Anxiety→ Behavioral intentions→ HDBs		-0.012	0.005	(-0.023, -0.003)	0.006
Behavioral intentions→ Action planning→ HDBs		0.035	0.009	(0.020, 0.054)	< 0.001
Maintenance self-efficacy→ Action planning→ HDBs		0.070	0.015	(0.041, 0.099)	< 0.001
Total effects					
Cues to action→ Behavioral intentions		0.066	0.014	(0.040, 0.094)	< 0.001
Subjective norm→ Behavioral intentions		0.153	0.033	(0.089, 0.217)	< 0.001
Anxiety→ Behavioral intentions		-0.194	0.027	(-0.247, -0.140)	< 0.001
Past HDBs→ Behavioral intentions		0.296	0.026	(0.246, 0.345)	< 0.001
Cues to action→ HDBs		-0.023	0.022	(-0.066, 0.020)	0.279
Outcome expectancies→ HDBs		0.041	0.009	(0.024, 0.061)	< 0.001
Perceived severity→ HDBs		0.023	0.008	(0.009, 0.042)	< 0.001
Subjective norm→ HDBs		0.044	0.010	(0.026, 0.065)	< 0.001
Perceived behavior control→ HDBs		0.047	0.026	(-0.006, 0.095)	0.076
Action self-efficacy→ HDBs		0.145	0.022	(0.104, 0.190)	< 0.001
Maintenance self-efficacy→ HDBs		0.057	0.025	(0.007, 0.107)	0.018
Behavioral intentions→ HDBs		0.219	0.034	(0.153, 0.286)	< 0.001
Anxiety→ HDBs		-0.113	0.022	(-0.155, -0.071)	< 0.001
Past HDBs→ HDBs		0.332	0.024	(0.286, 0.379)	< 0.001

Note. Abbreviations: *β*, standardized regression weights; *SE*, standard errors; 95% *CI*, 95% confidence interval; HDBs, healthy dietary behaviors. The path names (e.g., H1a) correspond to the same paths shown in Fig. 1. We added the correlations between subjective norm and outcome expectancies, subjective norm and perceived behavior control, outcome expectancies and perceived behavior control, as well as subjective norm and perceived severity, for modification

Preliminary targeted interventions were conducted among adolescents, resulting in increased adoption of healthy dietary behaviors, indicating a certain level of effectiveness, particularly in targeting specific constructs within the integrated model [12], supporting the hypothesis H3. The action self-efficacy has demonstrated a stronger effect in the intervention, indicating its significance as a key focus of interventions. Specially, enhancing subjective norms potentially boost self-efficacy. Adolescents are encouraged to share information about healthy eating with peers, providing descriptive norms to improve self-efficacy in adopting healthy dietary

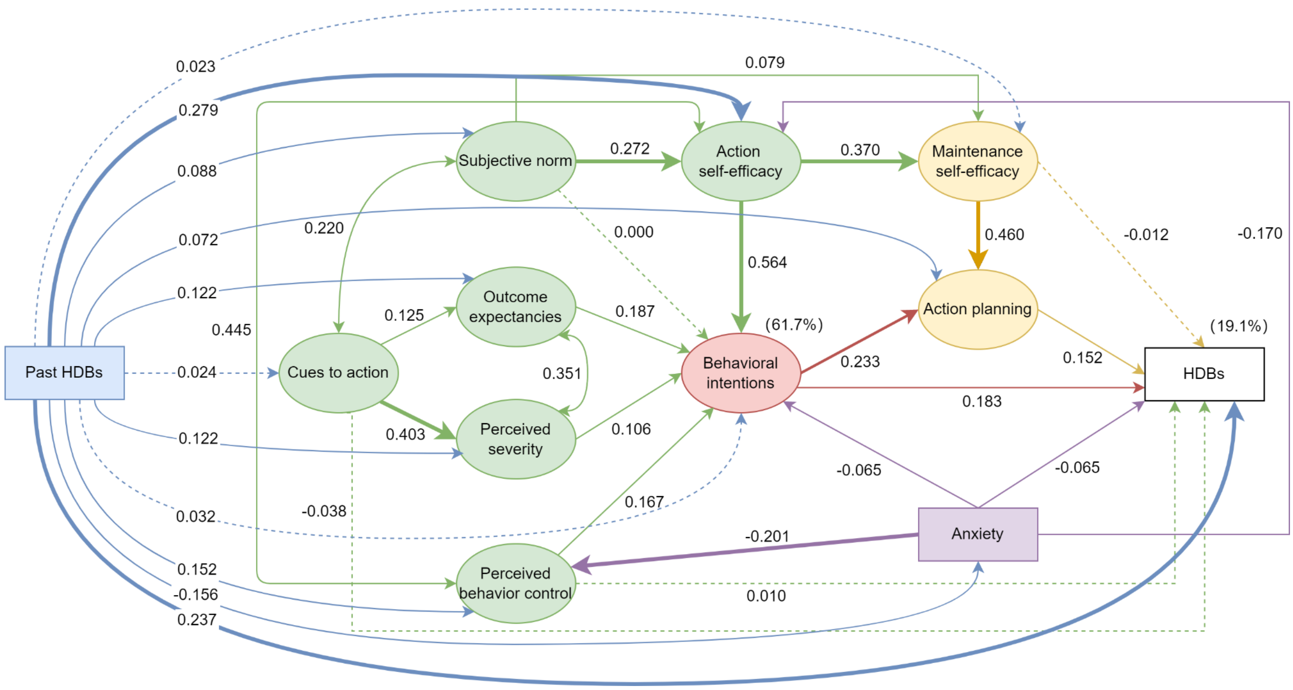

Fig. 2 The final integrated model. Note. Abbreviation: HDBs, healthy dietary behaviors. The final model displays labeled effect sizes next to each path, with solid arrows indicating statistical significance, and bold solid arrows indicating direct effect sizes above 0.200. Dashed arrows represent non-statistical significance. Specially, blue represents past HDBs and its paths, green is for motivational constructs and their paths, purple indicates anxiety and its paths, red denotes behavioral intentions and its paths, and yellow suggests volitional constructs and their paths. The percentages in the parentheses indicate the variance in behavioral intentions and HDBs accounted for by the model

behaviors [21, 43, 44]. Furthermore, interventions should steer clear of inducing negative emotional arousal, opting instead to offer improved emotion regulation strategies to mitigate emotional eating tendencies, enhance overall efficacy perceptions, and ultimately foster healthier dietary behaviors [19, 45].

Some limitations are acknowledged. First, the integrated model explained a high proportion of variance in behavioral intentions, but it presented a lower proportion of variance for actual healthy dietary behaviors (19.1%). The future research could incorporate additional variables, such as coping planning and self-control strategies, to bridge behavioral intentions and dietary behaviors or explore on a specific dietary behavior. Second, this study did not implement tailored interventions based on different phases that individuals belonged to, due to the unsuitability of the school environment for refining students into multiple population intervention; however, it established a foundation for future research in developing more customized approaches. Additionally, the interventions in this study were self-designed based on relevant constructs. Future interventions may benefit from integrating behavior change techniques to establish a standardized process [46, 47]. Third, behavioral measurements relied on self-reported questionnaires, which lacks objective indicators but is cost-effective. Lastly, the data were collected in rural areas of China, so caution is needed in extrapolating the findings to the broader adolescent population.

Table 4 The analyses for the discontinuity patterns of model variables at different behavior change phases

Variables	Behavior change phases, $n = 1298$, *Mean* (*SE*)				One-Way ANOVA, *F*	Post hoc (Games-Howell), *MD*			Polynomial, *F*		
	Non-intenders (1, $n = 477$)	Intenders (2, $n = 222$)	Planners (3, $n = 225$)	Actors (4, $n = 374$)		2 − 1	3 − 2	4 − 3	Liner	Quadratic	Cubic
Cues to action	3.56 (0.06)	3.71 (0.10)	3.96 (0.08)	3.65 (0.07)	4.489^{b}	0.14	0.25	-0.30^{a}	2.706	7.951^{b}	2.809
Outcome expectancies	4.48 (0.05)	5.02 (0.06)	4.91 (0.06)	4.95 (0.05)	24.178^{c}	0.53^{c}	-0.11	0.04	46.089^{c}	18.870^{c}	7.575^{b}
Perceived severity	4.04 (0.05)	4.38 (0.08)	4.26 (0.08)	4.40 (0.06)	8.552^{c}	0.34^{b}	-0.12	0.15	18.698^{c}	2.160	4.799^{a}
Subjective norm	4.10 (0.05)	4.53 (0.06)	4.49 (0.06)	4.55 (0.05)	19.91^{c}	0.44^{c}	-0.04	0.06	44.571^{c}	11.139^{b}	4.020^{a}
Perceived behavior control	3.77 (0.05)	4.47 (0.06)	4.43 (0.06)	4.39 (0.04)	51.506^{c}	0.70^{c}	-0.03	-0.04	99.148^{c}	48.141^{c}	7.230^{b}
Behavioral intentions	3.61 (0.04)	5.25 (0.02)	4.68 (0.07)	4.76 (0.05)	223.821^{c}	1.64^{c}	-0.57^{c}	0.08	316.504^{c}	231.833^{c}	123.127^{c}
Action self-efficacy	2.51 (0.02)	2.90 (0.03)	2.94 (0.03)	2.93 (0.02)	86.500^{c}	0.40^{c}	0.03	-0.01	193.831^{c}	59.794^{c}	5.876^{a}
Maintenance self-efficacy	3.15 (0.05)	3.50 (0.08)	4.21 (0.07)	3.76 (0.06)	49.671^{c}	0.35^{b}	0.710^{c}	-0.45^{c}	92.046^{c}	36.005^{c}	20.963^{c}
Action planning	2.93 (0.04)	3.22 (0.06)	5.08 (0.03)	4.00 (0.06)	278.229^{c}	0.28^{b}	1.87^{c}	-1.09^{c}	441.444^{c}	139.318^{c}	253.926^{c}
Anxiety	2.02 (0.02)	1.90 (0.03)	1.94 (0.03)	1.88 (0.02)	10.251^{c}	-0.12^{b}	0.04	-0.06	24.406^{c}	1.516	4.831^{a}

Note. Abbreviations: *SE*, standard error; *MD*, mean difference. $^{a}P < 0.05$, $^{b}P < 0.01$, $^{c}P < 0.001$

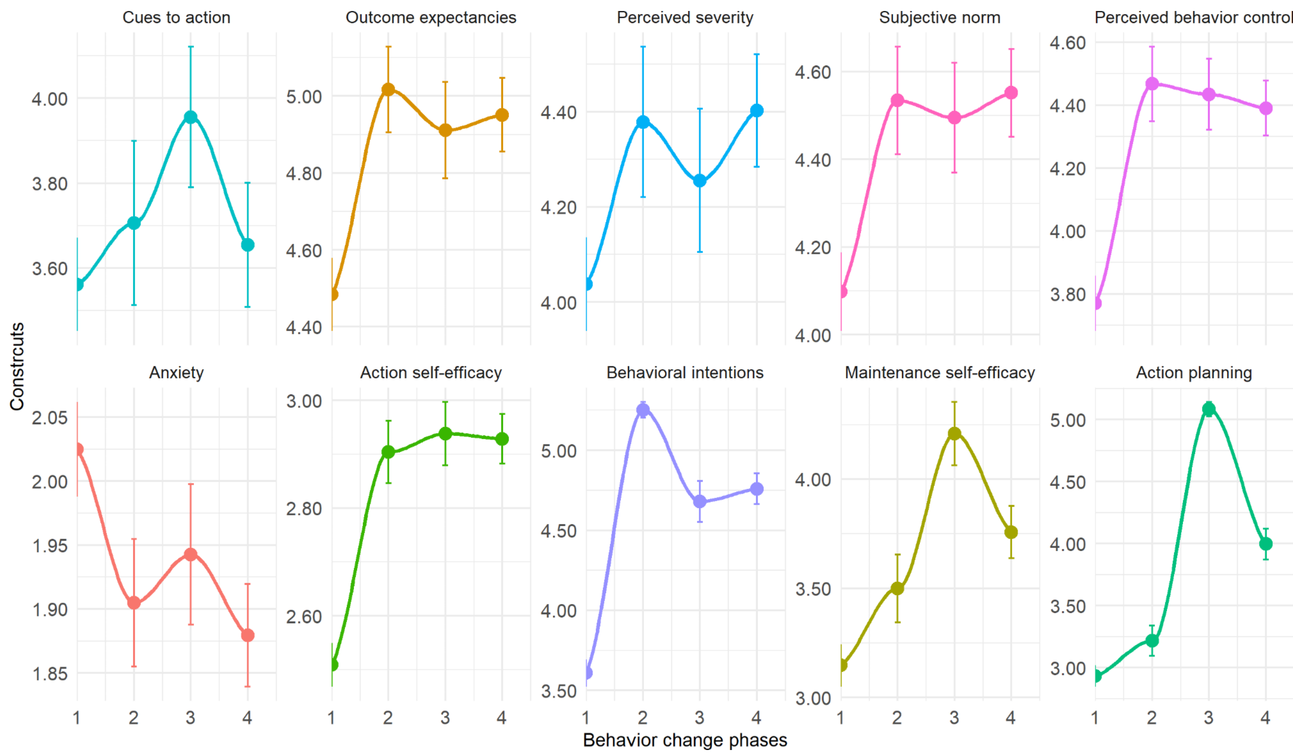

Fig. 3 Error bar and trend line plots for the discontinuity patterns of model variables. Note. The figure illustrates discontinuity patterns of model variables, with the Y-axis representing the mean values of each variable and the 95% confidence intervals. The X-axis indicates the behavior change phases, with 1 representing Nonintenders, 2 representing Intenders, 3 representing Planners, and 4 representing Actors

Table 5 Pairwise parameter comparisons across the control and intervention groups

Paths	School A (the control)			School B (the intervention)			C.*R.*
	β	95% *CI*	*P*	*β*	95% *CI*	*P*	
Direct effects							
Cues to action→ Perceived severity	0.411	(0.341, 0.480)	< 0.001	0.392	(0.294, 0.483)	< 0.001	-0.222
Cues to action→ Outcome expectancies	0.119	(0.057, 0.182)	< 0.001	0.140	(0.056, 0.224)	0.001	0.346
Cues to action→ HDBs	-0.038	(-0.091, 0.016)	0.167	-0.048	(-0.122, 0.028)	0.209	-0.131
Perceived severity→ Behavioral intentions	0.147	(0.066, 0.233)	< 0.001	0.028	(-0.065, 0.120)	0.536	-2.363[a]
Outcome expectancies→ Behavioral intentions	0.203	(0.109, 0.297)	< 0.001	0.152	(0.047, 0.265)	0.004	-1.091
Perceived behavior control→ Behavioral intentions	0.193	(0.109, 0.276)	< 0.001	0.100	(0.047, 0.266)	0.197	-1.317
Perceived behavior control→ HDBs	-0.007	(-0.081, 0.064)	0.857	0.054	(0.047, 0.267)	0.283	1.045
Subjective norm→ Action self-efficacy	0.264	(0.194, 0.337)	< 0.001	0.294	(0.047, 0.268)	< 0.001	0.326
Subjective norm→ Behavioral intentions	-0.030	(-0.099, 0.038)	0.356	0.066	(0.047, 0.269)	0.225	1.729
Subjective norm→ Maintenance self-efficacy	0.064	(-0.009, 0.137)	0.081	0.116	(0.047, 0.270)	0.022	1.054
Action self-efficacy→ Behavioral intentions	0.486	(0.374, 0.602)	< 0.001	0.704	(0.047, 0.271)	< 0.001	2.832[b]
Action self-efficacy→ Maintenance self-efficacy	0.300	(0.208, 0.383)	< 0.001	0.489	(0.047, 0.272)	< 0.001	3.459[c]
Maintenance self-efficacy→ Action planning	0.457	(0.389, 0.524)	< 0.001	0.454	(0.047, 0.273)	< 0.001	-0.676
Maintenance self-efficacy→ HDBs	-0.024	(-0.090, 0.044)	0.505	0.022	(0.047, 0.274)	0.686	0.808
Anxiety→ Behavioral intentions	-0.076	(-0.135, -0.017)	0.013	-0.053	(0.047, 0.275)	0.160	0.536
Anxiety→ Action self-efficacy	-0.192	(-0.259, -0.121)	< 0.001	-0.130	(0.047, 0.276)	0.014	1.520
Anxiety→ Perceived behavior control	-0.198	(-0.257, -0.140)	< 0.001	-0.203	(0.047, 0.277)	< 0.001	0.018
Anxiety→ HDBs	-0.060	(-0.116, -0.008)	0.025	-0.068	(0.047, 0.278)	0.047	-0.087
Behavioral intentions→ Action planning	0.216	(0.150, 0.282)	< 0.001	0.275	(0.047, 0.279)	< 0.001	0.847
Behavioral intentions→ HDBs	0.213	(0.125, 0.299)	< 0.001	0.118	(0.047, 0.280)	0.057	-1.518
Action planning→ HDBs	0.180	(0.105, 0.257)	< 0.001	0.093	(0.047, 0.281)	0.068	-1.364

Note. Abbreviation: *β*, standardized regression weights; 95% *CI*, 95% confidence interval; HDBs, healthy dietary behaviors; C.R., the critical ratios for differences between parameters. Standardized estimates of the path regression weights were performed in the "measurement weights" model constrained all factor loadings to be equal across groups to control for the effects of measurement. [a]$P<0.05$, [b]$P<0.01$, [c]$P<0.001$

Conclusions

The staged integrated model developed in this study offers an operational framework by providing a detailed understanding of the determinants of healthy dietary behaviors in adolescents across different phases of behavior change. It encompasses motivational constructs, such as outcome expectancies, perceived severity, subjective norms, and action self-efficacy, along with behavioral intentions, and volitional constructs, including maintenance self-efficacy and action planning. Additionally, anxiety is identified as an emotional barrier that hinders positive cognition and behaviors throughout the dietary behavior modification process. This staged integrated model provides valuable insights for designing interventions that target specific constructs at different phases, with particular emphasis on enhancing action self-efficacy. Further investigation into bridging behavioral intentions and actual behaviors is essential to deepen our understanding of specific healthy dietary behaviors in adolescents.

Abbreviations

HBM	Health Belief Model
TPB	Theory of Planned Behavior
HAPA	Health Action Process Approach
HDBs	Healthy dietary behaviors
SEM	Structural equation modeling
$\chi 2$/df	The Chi-square statistics divided by the degrees of freedom
RMSEA	The root mean square error of approximation
CFI	The comparative fit index
GFI	The goodness-of-fit index
TLI	The Tucker-Lewis index
NFI	The normed fit index
SE	Standard error
MD	Mean difference
β	Standardized regression weights
95% *CI*	95% confidence interval
C.R.	The critical ratios for differences between parameters

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-21101-8.

Supplementary Material 1: Additional file 1: Figure S1. Survey and behavior change workflow.

Supplementary Material 2: Additional file 2: Table S1 and S2. A detailed description and psychometric properties of the psychological constructs..

Supplementary Material 3: Additional file 3: Table S3. The full results of indirect effects in the final integrated model.

Supplementary Material 4: Additional file 4: Table S4. Goodness-of-fit statistics for tests of multigroup invariance.

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Author contributions

QLL have made substantial contributions to the concept and design of the study. QJL, HX, ZY, LY, and RS contributed to the statistical analysis and interpretation of data. QJL was a major contributor in writing the manuscript, and QLL, WT, YL, SL substantively revised it. QLL and QJL had full access to all the data in the study, and QLL took responsibility for the integrity of the data and the accuracy of the data analysis. All authors reviewed and approved the final manuscript.

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Data availability

The datasets generated and analysed during the current study are not publicly available due to the protection of adolescents' privacy but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

All participants agreed to the investigation and provided informed written consent to participate in this study. For children under 16 years of age, consent was also obtained from their parents/guardians, including verbal or written consent. The study received ethical approval from the Medical Ethics Committee of Sichuan University (NO. 20140307 and Gwll2023117).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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