

CSF3R and Action Control Moderate the Relationship Between Stress and Healthy Diet: Preliminary Evidence for an Individualized Model of Stress Effects on Health Behavior (Postprint)

Authors: The user has provided a very short input: “胡月琴” . This appears to be a Chinese name. Let me analyze the requirements:

1. The user wants me to translate from Simplified Chinese to English with highest accuracy and academic tone
2. Critical requirements include preserving LaTeX commands, citation commands, and `···`tags
3. However, the input “胡月琴” is just a name, not a paragraph with tags
4. The glossary provided only includes “机器学习 => machine learning” and “深度学习 => deep learning” , which are not relevant here

Since the input is just a name without any tags, LaTeX commands, or citations, I should simply translate it appropriately. “胡月琴” is a Chinese name that should be transliterated to English.

The standard academic convention for Chinese names is: - Use pinyin transliteration - Capitalize the surname and given name appropriately - Typically format as “Yueqin Hu” (given name first, surname last) in English contexts, or sometimes “Hu Yueqin” (surname first) depending on the style guide

In academic papers, Chinese names are often written in the Western order (given name first) when the paper is in English, but sometimes the original order is preserved. The most common and acceptable approach is to use the pinyin with proper capitalization: “Yueqin Hu” .

Since there are no tags in the input, I don't need to add any. The output should be just the translated name.

Let me check the requirements again: - “Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent).” - “Keep one output paragraph per input paragraph; do not merge or split paragraphs.” - “Maintain exact count and IDs of `···`tags”

The input has no paragraphs and no tags, so the output should be just the name translation without any tags.

The name “胡月琴” breaks down as: - 胡 (Hú) - surname - 月琴 (Yuèqín) - given name

Standard transliteration: “Yueqin Hu” (Western order) or “Hu Yueqin” (Chinese order). In academic contexts, both are acceptable, but “Yueqin Hu” is more common in English-language publications to conform to Western naming conventions.

I'll go with “Yueqin Hu”, Wang Lizhong, The user has provided a very short input: “陈钢”. This is a Chinese name. The task is to translate it from Simplified Chinese to English with the highest accuracy and academic tone, following all the critical requirements.

Let me analyze the requirements: 1. Preserve ALL LaTeX commands and placeholders - not applicable here as there are none 2. Preserve ALL citation commands - not applicable here 3. **PRESERVE ALL ...paragraph wrapper tags EXACTLY** - not present in the input 4. Maintain academic tone and formal scientific writing style - this is a name, so it should be transliterated 5. Use precise technical terminology - obey the glossary strictly - not applicable 6. Preserve section structure and paragraph organization - not applicable 7. Translate all content completely - do not omit any information

The input is just “陈钢”. This is a Chinese name. In academic contexts, Chinese names are typically transliterated using Pinyin. “陈钢” would be “Chen Gang”

However, I need to check if there are any tags. The input is just plain text “陈钢”. There are no paragraph wrapper tags. According to the output rules, I should return ONLY the translated text. The user hasn't provided any paragraph tags, so I should not add them.

The glossary provided is: 机器学习 => machine learning 深度学习 => deep learning

These are not relevant to this translation.

So the translation should be “Chen Gang”. In academic papers, Chinese names are often written with the surname first, followed by the given name, either as “Chen Gang” or sometimes “Gang Chen” depending on the author's preference and the journal's style. However, the standard Pinyin transliteration preserves the Chinese order: “Chen Gang”.

Since this is a name and there are no structural tags, I should just provide the transliterated name. The user might be asking for the translation of a person's name, which in academic context would be the Pinyin transliteration.

Let me consider the output rules: - Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent). - Keep one output paragraph per input paragraph; do not merge or split paragraphs. - **Maintain exact count and IDs of ...tags** - if input has N paragraph tags, output must have exactly N paragraph tags with matching IDs

Since the input has, The user has provided a name “甘怡群” which appears to be a Chinese name. This is likely a request to translate this name into English.

In academic contexts, Chinese names are typically transliterated using the Pinyin system. The name “甘怡群” would be:

- 甘 (Gān) - surname
- 怡群 (Yīqún) - given name

The standard academic convention is to write Chinese names with the surname first, followed by the given name, either as: 1. Gan Yiqun (most common in English publications) 2. GAN Yiqun (all caps for surname) 3. Gan, Yiqun (comma-separated)

Given that this is for academic translation and the user is asking me to translate it (likely for a citation or reference), I should provide the standard academic transliteration.

The most common and recommended format for academic papers is “Gan Yiqun” or “GAN Yiqun” . I ll provide the standard form.

However, I need to consider the context. The user might want this for a reference list or citation. In that case, I should provide the name in the format typically used in English academic publications.

Let me think about the specific requirements: - The user said “甘怡群” without any context - This is likely a name that needs to be transliterated - In academic writing, Chinese names are usually written in Pinyin with the surname first

The standard translation/transliteration would be “Gan Yiqun” .

But wait - the user might want me to treat this as a standalone request. Since there are no tags, LaTeX commands, or other structural elements, I should just provide the transliterated name directly.

I should also consider if this is a well-known researcher whose name has a specific English spelling they prefer. “甘怡群”is a known psychologist at Peking University. Her name is typically published as “Gan, Yiqun” or “Yiqun Gan” in English publications.

Looking at her publications, she uses “Gan Yiqun” or “Yiqun Gan” depending on the journal style. The most common format in reference lists would be “Gan, Yiqun” or “Gan Yiqun” .

For a direct translation request like this, I should provide the standard Pinyin transliteration. The most appropriate academic format would be “Gan Yiqun” (surname + given name).

Let me provide

Date: 2023-10-09T00:00:00+00:00

Abstract

Stress responses in eating behavior vary considerably across individuals; some people tend to consume more sweets and other high-calorie foods under stress, whereas others show no such tendency. This variation may be associated with functional dominance patterns of the vagus nerve system, which can be classified as either trophotropic or ergotropic. The present study examined 14,675 Chinese adults and integrated the Health Action Process Approach (HAPA) model with vagal dominance theory. Our findings revealed that stress significantly predicted reduced healthy eating intention, which subsequently led to decreased healthy eating behavior. The CSF3R gene polymorphism rs4076431 and its linked loci rs4498771, rs10752589, and rs9660229 moderated the relationship between stress and healthy eating intention, while action control moderated the association between healthy eating intention and healthy eating behavior. Specifically, for rs4076431, the negative relationship between stress and healthy eating intention was stronger among individuals with the AA genotype (trophotropic type) compared to G allele carriers (ergotropic type). Higher action control scores were associated with greater engagement in healthy eating behavior, which was less influenced by stress and healthy eating intention. Based on these results, we propose a personalized model of stress effects on health behavior, suggesting that health management under stress should consider multiple levels of influence, including physiological, behavioral, and contextual factors.

Full Text

Moderating Effects of CSF3R and Action Control on the Relationship Between Stress and Healthy Eating: Preliminary Evidence for an Individualized Model of Stress Impact on Health Behavior

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Abstract

Stress affects eating behavior differently across individuals: some people tend to consume more sweets and high-calorie foods when stressed, while others show no such tendency. This variation may be related to two types of functional dominance in the vagal nervous system—trophotropic or ergotropic. Using a sample of 14,675 Chinese adults, this study integrated the Health Action Process Approach (HAPA) with vagal dominance theory and found that stress significantly predicted reduced healthy eating intentions and, subsequently, reduced healthy eating behavior. The CSF3R gene rs4076431 and its linked loci

rs4498771, rs10752589, and rs9660229 moderated the relationship between stress and healthy eating intentions, while action control moderated the relationship between healthy eating intentions and behavior. Using rs4076431 as an example, the negative relationship between stress and healthy eating intentions was stronger among individuals with the AA genotype (trophotropic) than among G allele carriers (ergotropic). Higher action control scores were associated with more healthy eating behaviors, which were less influenced by stress and healthy eating intentions. Based on these results, we propose an individualized model of stress impact on health behavior, suggesting that stress management for health should consider multiple factors across physiological, behavioral, and contextual levels.

Keywords: healthy eating, perceived stress, gene, vagal tone

Classification Code: B845

1. Introduction

1.1 Stress and Healthy Eating

In recent years, with improvements in living standards and health awareness, the impact of stress on health behavior has attracted increasing attention from researchers and the public (e.g., Fodor et al., 2014). Because the effect of stress on health behavior is highly dependent on the specific behavior under discussion (Stults-Kolehmainen & Sinha, 2014), it is necessary to focus the discussion on specific health behaviors such as dietary behavior.

Healthy eating can be defined as a pattern of food intake that is beneficial to health or at least not harmful (Stevenson, 2017). There is currently consensus on the basic characteristics of an unhealthy diet, which include high intake of processed foods, sugar-sweetened beverages, trans and saturated fats, added salt and sugar, and low intake of fresh fruits, vegetables, nuts, and whole grains (de Ridder et al., 2017; Willett, 1994). Healthy eating recommendations typically call for a diversified and balanced diet (mentioned in 80% of guidelines), high in vegetables and fruits (94%), low in fat (93%), low in sugar (86%), and low in salt (96%). However, most measures of healthy eating focus on fruit and vegetable intake rather than including low fat, low sugar, and low salt components (de Ridder et al., 2017).

Recent research on stress and eating behavior has increased (e.g., Fodor et al., 2014), yet findings remain inconsistent (e.g., Araiza & Lobel, 2018; Siegrist & Rödel, 2006). The only meta-analysis to date (Hill et al., 2021) found that stress was associated with increased consumption of unhealthy foods (Hedges' $g = 0.116$) and decreased consumption of healthy foods (Hedges' $g = -0.111$). Payne et al. (2005) showed that stress had adverse effects on exercise but did not affect fruit and vegetable consumption, though it did influence intentions and actual intake of candy and snacks. The reasons underlying the stress-eating association

may be multiple. People may use food as a source of comfort, unintentionally or intentionally employing it as a coping strategy for stress, thus eating more when stressed (Araiza & Lobel, 2018; Groesz et al., 2012). Alternatively, stress may increase energy demands, as Liu et al. (2017) found that men engaged in high-intensity work consumed more calories from high-fat foods than those in low-intensity work, based on an 18-item food frequency questionnaire (FFQ).

Although some studies have found that stress increases food intake (e.g., Wardle et al., 2000), others have found that food consumption decreases (e.g., Stone & Brownell, 1994; Torres & Nowson, 2007). What determines these different responses to stress? While research on stress and health behavior associations is abundant in health psychology (Heuse et al., 2021; Payne et al., 2005), a recent meta-analysis highlights inconsistency in findings. Due to significant heterogeneity across studies, the overall relationship between stress and food intake shows only a small positive effect (Hill et al., 2021). Individual differences in dietary responses to stress appear to be the main source of observed heterogeneity. The individual differences model posits that stress effects on eating are determined by learning history, attitudes, or biological individual differences, yet research examining individual differences as moderators remains scarce (Ruf et al., 2022). The innovation of this paper lies in exploring moderating factors affecting the stress-food intake relationship from both biological differences (genes) and personality differences (action control). This study attempts to integrate stress and vagal dominance theory within the Health Action Process Approach (HAPA; Schwarzer et al., 2011) framework to examine the relationship between stress and healthy eating and its individual differences, thereby providing theoretical support and intervention direction for health management under stress.

1.2 Stress and the Health Action Process Model

Previous research has examined direct relationships between stress and health behavior but has not integrated stress into theoretical models of health behavior. The Health Action Process Approach (HAPA) seeks to explain the development of health behavior. Integrating HAPA with stress models may further clarify the relationship between stress and health behavior.

HAPA (Schwarzer & Hamilton, 2020) divides health behavior change into two phases: a motivational phase and a volitional phase. The outcome of the motivational phase is intention formation, defined as an individual's motivation to perform a specific behavior to achieve a desired goal. Meta-analyses have confirmed positive relationships between intentions and various health behaviors, including healthy eating (e.g., Armitage & Conner, 2001). However, intention alone appears insufficient for behavior change (Webb & Sheeran, 2007). According to HAPA, individuals who form intentions enter the volitional phase, where developing action plans and coping plans are considered effective self-regulation strategies for overcoming action barriers and achieving target behaviors.

Numerous studies have shown that stress has direct effects on dietary intentions.

A 2007 review found that stress increased cravings for high-calorie, high-fat, and high-sugar foods (Torres & Nowson, 2007). A 2019 study found negative associations between perceived stress and healthy eating intentions (Klatzkin et al., 2019). Reichenberger et al. (2021) used ecological momentary assessment to explore mediating mechanisms between stress and dietary intentions, finding that stress reduced self-regulation capacity, leading to cravings for unhealthy foods.

In the HAPA model, the main factors influencing intention or motivation are risk perception and outcome expectancies. However, given that stress impacts on health behavior are now widely recognized (Shuck et al., 2021), stress should be considered an important barrier to health behavior intentions (Groesz et al., 2012). Yet current HAPA models have not incorporated stress effects. High stress is characterized by time pressure, goal conflict, and unstable intentions (Lazarus, 1995). In such contexts, people may prefer time-saving, convenient fast-food solutions that quickly provide calories and improve mood, compared to healthy diets rich in fruits and vegetables. Therefore, in the motivational phase, stress may affect people's willingness to eat healthily, making them more inclined toward unhealthy foods high in sugar and fat. In the volitional phase, stress constitutes a barrier to implementing health actions, while action control can help overcome these obstacles through appropriate self-regulation (Sniehotta, 2009).

The concept of action control derives from self-regulation processes. Self-regulation refers to various efforts made to change behavior (Baumeister et al., 2018). Self-monitoring, awareness of standards, and effort all belong to self-regulation processes. Sniehotta et al. (2005) termed these three self-regulation processes "action control." Action control can be considered the predictor closest to behavior in the volitional phase (Sniehotta et al., 2005). Some studies have shown that action control can influence the intention-behavior relationship and is an effective personal resource for facilitating health behavior change (e.g., Schwarzer et al., 2007; Sniehotta et al., 2005).

Although HAPA models have not considered individual differences, personality (Diop et al., 2021), childhood experiences (Pilkington et al., 2021), and social environments (Peeters, 2018) have all been shown to relate to healthy eating. Genes represent the most fundamental individual differences, making it particularly meaningful to develop an individualized HAPA model by examining how genetic differences affect healthy eating under stress. Recent research has found that neuropeptide Y (NPY) modulates the relationship between vagal (parasympathetic) activity and stress resilience. The NPY gene has potential vagal function in stress regulation (Chang et al., 2016).

1.3 Stress and Vagal Nervous System Dominance Theory

Individual differences in stress and unhealthy eating may relate to the evolution of the hypothalamic system. Gellhorn's (1967) classic terminology "trophotropic

vs. ergotropic” labeled the parasympathetic nervous system as trophotropic and the sympathetic nervous system as ergotropic. Porges (1992) redefined these terms to represent individual differences in environmental stress responses: trophotropic primarily refers to vagal functions that form the basis of regeneration and recovery, while ergotropic individuals tend to prepare for fight-or-flight responses, thereby suppressing hunger and satiety. The adaptive value of vagal function remains debated (Porges, 1995). Nevertheless, research generally agrees that individuals dominated by the trophotropic system show lower activation of the hypothalamic-pituitary-adrenal (HPA) axis under stress, exhibiting vagal dominance symptoms: increased food intake and weight gain (Everly & Lating, 2019). Conversely, ergotropic individuals under stress tend toward HPA overactivation with increased sympathetic activity: decreased food intake and weight loss (McLaughlin et al., 2015).

Vagal dominance theory attempts to explain these individual differences in stress responses. Some nerve fibers in the vagus nerve are parasympathetic fibers—visceral motor parasympathetic fibers that constitute the main component of the vagus nerve. These fibers are distributed to organs in the thoracic and abdominal cavities, such as the trachea, bronchi, lungs, heart, and abdominal organs including the liver, pancreas, spleen, kidneys, adrenal glands, stomach, and transverse colon, regulating the activity of these organs. Individuals with higher vagal dominance tend to have more adaptive cognitive and emotional responses to various stressors (Porges, 2007). Higher vagal dominance reduces adverse reactions to chronic adversity and the risk of resulting mental illness (Kogan et al., 2012). Additionally, higher vagal dominance predicts better recovery from psychosocial stress (Souza et al., 2007). Conversely, decreased vagal dominance correlates positively with impaired post-stress recovery of cardiovascular, endocrine, and immune markers, and predicts susceptibility to future stress-related health conditions such as obesity (Kogan et al., 2012; McLaughlin et al., 2015). Vagal dominance is used to measure personal characteristics, and these findings strengthen previous associations between greater vagal dominance and emotion regulation capacity (Souza et al., 2007).

Individual differences in vagal dominance are considered an important factor in individual resilience to stress (McLaughlin et al., 2015; Smeets, 2010). However, we know little about the molecular mechanisms underlying individual differences in vagal dominance under conditions of high chronic stress.

CSF3R (Colony Stimulating Factor 3 Receptor) is a protein-coding gene. Diseases associated with CSF3R include neutrophilia, hereditary neutropenia, and severe congenital autosomal recessive neutropenia. Its related pathways include autophagy and RNA polymerase I promoter opening. The brain plays a central role in cognitive, emotional, and behavioral responses to stressful events. However, it is impossible to obtain RNA samples from brain regions in healthy subjects. Sullivan et al. (2006) assessed the comparability of gene expression in the central nervous system (CNS) and peripheral blood, finding significant gene expression similarity between whole blood and multiple CNS tissues at

the transcriptome level. However, it remains unclear whether gene expression in peripheral blood cells is a useful proxy for gene expression in CNS tissues (Sullivan et al., 2006). The immune system communicates bidirectionally with the CNS and endocrine system. Acute psychological stress increases circulating inflammatory factors (Steptoe et al., 2007), while chronic psychological stress is associated with immune dysfunction (Glaser & Kiecolt-Glaser, 2005). Peripheral blood leukocytes play a role in stress-induced inflammatory and immune responses by producing numerous bioactive molecules, including cytokines. Some of these directly stimulate the HPA axis (Chesnokova & Melmed, 2002) or express specific receptors for stress mediators such as hormones, neurotransmitters, growth factors, and cytokines. Although gene expression profiles in peripheral blood leukocytes cannot directly map CNS responses, they may help indirectly assess complex systemic reactions induced by various stressors. Therefore, the gene regulatory role of CSF3R has received recent attention (Kawai et al., 2007). Different CSF3R genotypes may have different expression levels, leading to different cytokine production in stress responses. Thus, studying CSF3R genotypes may help objectively evaluate psychological stress responses.

1.4 Purpose and Hypotheses of This Study

HAPA focuses on risk perception for health behavior initiation and maintenance but has not incorporated individual and environmental factors. Our model emphasizes an important contextual factor: stress. Additionally, we include genotypes closely related to vagal nervous system dominance as moderators of individual differences in the motivational phase. Since action control is an important moderator in the volitional phase in classic HAPA models, we also include individual differences in action control as a moderator in the volitional phase. Therefore, we propose an individualized health action model for stress. Please refer to Figure 1 [Figure 1: see original paper].

This study aims to propose and test a new theory regarding the relationship between stress and healthy eating. According to the individualized health action model for stress, we argue that individuals' healthy eating behaviors under stress may change, but this change depends on specific personal characteristics and healthy eating intentions. In the motivational phase of the individualized health action model, both vagal dominance and its genetic basis may hinder healthy eating behavior. CSF3R was used as a candidate gene because it has proven effects in vagal function dominance (Kawai et al., 2007). We hypothesized that this gene could explain individual differences in stress responses; that is, in the motivational phase of the individualized health action model, when facing stress, people carrying specific alleles may be more likely to reduce healthy eating intentions than others. In the volitional phase of the individualized health action model, individual characteristics of action control play an important moderating role: individuals with low action control are more likely to translate unhealthy eating intentions into behavior. We conducted a large-scale national survey of Chinese adults to test the above hypotheses.

2. Method

2.1 Participants

We recruited 14,675 participants from WeGene' s customer base. As part of WeGene' s personal genome service (Kang et al., 2020), all participants completed genotyping using gene chips (approximately 700,000 variant sites; 38% using Affymetrix WeGene V1 chip, 62% using Illumina Infinium Global Screening Array-24 v2.0 BeadChip). Participants provided informed consent and participated through WeGene' s online platform (WeChat social media channels, mobile apps, and websites). Participants could opt out by emailing customer service. WeGene' s customers cover people aged 18 and above, representative in terms of age, region, and occupation. Upon completion, each participant received 500 points in their WeGene account. Inclusion criteria included being of Han Chinese ethnicity and passing five validity check items. All procedures complied with ethical standards of relevant national and institutional human subjects committees and the 1975 Helsinki Declaration as revised in 2008. All procedures were approved by Peking University Human and Animal Subjects Protection Committee (ID#2018-10-03e) and the Chinese Human Genetic Resources Management Office ([2021]CJ2171).

The mean age of all participants was 28.17 years (SD = 7.09; range = 18-65). There were 6,363 male participants (43.4%) and 8,267 female participants (56.3%); 45 cases (0.3%) had missing data. Among participants, 3,601 (24.5%) held master' s degrees or higher, 8,614 (58.7%) held bachelor' s degrees, 1,597 (10.9%) held college diplomas, 817 (5.6%) had high school education, and the remaining 46 (0.3%) had less than high school education.

2.2 Measures

Stress. The Chinese Perceived Stress Scale (CPSS) assesses individual stress and is suitable for evaluating perceived stress in various populations. The scale was developed by Cohen et al. (1983) and revised in Chinese by Yang Tingzhong and Huang Hanteng (2003). The scale has good reliability and validity. It has two dimensions: tension and loss of control. Total scores are calculated, with higher scores indicating greater psychological stress. It includes 10 items (e.g., "In the past month, how often have you felt upset because something unexpected happened"). Respondents used a 1-5 Likert scale where 1 = never and 5 = very often. In this study, the internal consistency coefficient was 0.869.

Dietary Intention and Behavior. We used the HAPA variable assessment scale by Schwarzer and Luszczynska (2008) to measure dietary intention and behavior. Healthy eating intention was assessed through two items related to healthy eating intention (e.g., "I intend to regularly eat fruits and vegetables"). Items used a 1-4 Likert scale ranging from 1 (completely incorrect) to 4 (completely correct). Two additional items measured actual healthy eating behavior ("How many servings of fruit/vegetables do you eat on average per day?"). To help participants respond accurately, examples of serving sizes were provided.

All these scales have reported satisfactory reliability and validity in previous studies. In this study, the internal consistency coefficient was 0.935.

Action Control. We used the scale developed by Sniehotta et al. (2005) to measure action control for health behaviors. The instrument consists of six items addressing self-monitoring, awareness of standards, and self-regulatory effort over the past four weeks, such as “In the past four weeks, I have always been aware of my prescribed diet plan” and “I try to act according to my standards.” All items used a 1-6 Likert scale ranging from 1 (completely incorrect) to 6 (completely correct). In this study, the internal consistency coefficient was 0.749.

2.3 Genotyping, Quality Control, and Imputation

Participants’ saliva samples were genotyped according to WeGene’ s protocol. Based on sex mismatch (15 individuals removed), disproportionate individual missingness (>5%; all individuals met this criterion), evidence of relatedness (one individual from each pair identified as second-degree or closer by KING was removed; 141 individuals removed; Manichaikul et al., 2010), inbreeding coefficient >0.2 or <-0.2 (also known as heterozygosity F statistic; all individuals met this criterion), and non-Han ethnicity (assessed by principal component analysis and two-dimensional clustering analysis using 1000 Genomes Project Phase 3 data; Bycroft et al., 2018; 284 individuals removed), some individuals were excluded from further analysis. Quality control parameters for single nucleotide polymorphisms (SNPs) were as follows: SNP missingness >0.02 (53,209 SNPs removed); SNP deviation from Hardy-Weinberg equilibrium <1e-5 (7,349 SNPs removed). Genotype data were imputed using Eagle/Minimac4 with default parameters (sliding window size of 10 Mb, step size of 3 Mb) based on 1000 Genomes Project Phase 3 v5 reference haplotypes. Post-imputation filtering was performed by removing SNPs with imputation quality (i.e., Minimac R2) <0.3 (35,588,204 SNPs removed), MAF <1% (5,409,717 SNPs removed), or missing rate >2% (0 SNPs removed). A final dataset of 14,675 individuals with 6,838,420 SNPs was included in the genetic association study.

3. Results

3.1 Descriptive Statistics

Descriptive statistics and correlations for variables in this study are shown in Table 1 . Missing data rates for all study variables ranged from 0% to 3.4%, all below 5%, making pairwise deletion appropriate for subsequent analyses. Genetic variables and other variables were obtained through different measurement methods, eliminating common method bias. Other variables controlled for common method bias through reverse-scored items (Zhou & Long, 2004). Stress, healthy eating intention, healthy eating behavior, and action control were all significantly correlated, $p < 0.001$. The gene (using SNP rs4076431 as an example) was not significantly correlated with these variables, $p > 0.05$. De-

mographic variables including sex, age, and education level showed significant correlations with the above variables and were therefore controlled as covariates in subsequent statistical models.

3.2 Stress and Health Behavior Process

According to the hypothesized model in Figure 1, we first used linear regression to examine the relationship between stress and healthy eating intentions and behaviors, following HAPA' s suggestion to test the mediating effect of healthy eating intention between stress and healthy eating behavior. Regression Model 1 in Table 2 shows that stress significantly predicted healthy eating intention, with higher stress associated with lower intention, $B = -0.034$, $SE = 0.002$, $p < 0.001$, $95\% CI = [-0.038, -0.030]$. Split-half validation results were consistent with these conclusions, with stress predicting intention in both half-samples, $B = -0.037$, $p < 0.001$, and $B = -0.031$, $p < 0.001$. Model 2 used stress and healthy eating intention to simultaneously predict healthy eating behavior, showing a significant effect of intention, with stronger intention associated with higher behavior scores, $B = 0.645$, $SE = 0.005$, $p < 0.001$, $95\% CI = [0.636, 0.654]$. The direct effect of stress was also significant, $B = -0.008$, $SE = 0.001$, $p < 0.001$, $95\% CI = [-0.010, -0.006]$. In split-half validation, the effect of intention on behavior was significant in both samples, $B = 0.633$, $p < 0.001$, and $B = 0.656$, $p < 0.001$. Bootstrap mediation testing found that the indirect effect of stress through intention was significant, with high stress predicting decreased healthy eating intention, which in turn predicted decreased healthy eating behavior, $B = -0.022$, $SE = 0.002$, $95\% CI = [-0.025, -0.019]$.

3.3 Individual Differences in the Stress-Health Behavior Process

We then tested the moderating effect of genes. We used regression analysis to examine the moderating effect of four SNPs in CSF3R (rs4076431, rs10752589, rs9660229, and rs4498771) on the relationship between stress scores and healthy eating. We used these four SNPs because they are located in adjacent genomic regions with strong linkage disequilibrium (all >0.8), forming a strong linkage block. Since results using these four SNPs showed the same pattern, we present only results from rs4076431.

Model 3 in Table 2 found that the gene significantly moderated the effect of stress on intention, with a significant stress \times gene interaction, $B = 0.013$, $SE = 0.004$, $p < 0.01$, $95\% CI = [0.004, 0.021]$. The stress \times gene interaction remained significant in split-half validation, $B = 0.013$, $SE = 0.006$, $p = 0.036$ in one half, and $B = 0.013$, $SE = 0.006$, $p = 0.040$ in the other half. Simple slope analysis revealed that for the homozygous AA genotype, the effect of stress on intention was $B = -0.041$, $SE = 0.003$, $p < 0.001$, $95\% CI = [-0.047, -0.035]$, while for G allele carriers (homozygous or heterozygous), the effect was $B = -0.029$, $SE = 0.003$, $p < 0.001$, $95\% CI = [-0.034, -0.022]$. Comparing the two, the negative effect of stress on healthy eating intention was larger in the AA genotype. Model 4 used healthy eating behavior as the outcome and found a significant stress \times

gene interaction on healthy eating behavior, $B = 0.008$, $SE = 0.004$, $p = 0.034$, but this moderating effect disappeared when Model 5 added healthy eating intention, supporting the mediating role of healthy eating intention—that is, the gene moderated the effect of stress on healthy eating intention, which in turn affected healthy eating behavior. Bootstrap moderated mediation testing (SPSS PROCESS macro Model 7) found that the gene significantly moderated the indirect effect of stress on healthy eating behavior, $B = 0.008$, $SE = 0.003$, 95% CI [0.002, 0.014]. Specifically, among AA genotype carriers, the indirect effect of stress on healthy eating behavior through intention was $B = -0.027$, $SE = 0.002$, 95% CI [-0.031, -0.023]; among G carriers, this indirect effect was $B = -0.018$, $SE = 0.002$, 95% CI [-0.023, -0.014]. Thus, the indirect negative effect of stress on healthy eating behavior was larger in the AA genotype.

Finally, we tested the moderating effect of action control. Model 6 showed a significant intention \times control interaction, $B = -0.066$, $SE = 0.003$, $p < 0.001$, 95% CI = [-0.072, -0.059], supporting the moderating role of control between healthy eating intention and behavior. This interaction remained significant in split-half validation, $B = -0.076$, $SE = 0.005$, $p < 0.001$ in one half, and $B = -0.058$, $SE = 0.004$, $p < 0.001$ in the other half. Simple slope analysis showed that for individuals with lower action control scores (control = 3), the effect of intention on behavior was $B = 0.670$, $SE = 0.006$, $p < 0.001$, 95% CI = [0.658, 0.681]; for those with medium control scores (control = 4), the effect was $B = 0.603$, $SE = 0.005$, $p < 0.001$, 95% CI = [0.593, 0.612]; for those with higher control scores (control = 6), the effect was $B = 0.469$, $SE = 0.008$, $p < 0.001$, 95% CI = [0.454, 0.485]. That is, higher action control scores were associated with weaker influence of intention on healthy eating behavior. Bootstrap moderated mediation testing (SPSS PROCESS macro Model 14) found that action control significantly moderated the indirect effect of stress on healthy eating behavior, $B = 0.0023$, $SE = 0.0002$, 95% CI [0.0018, 0.0027]. Specifically, among individuals with low action control scores, the indirect effect of stress on healthy eating behavior through intention was $B = -0.023$, $SE = 0.002$, 95% CI [-0.026, -0.020]; among those with medium control scores, it was $B = -0.021$, $SE = 0.001$, 95% CI [-0.023, -0.018]; among those with high control scores, it was $B = -0.016$, $SE = 0.001$, 95% CI [-0.018, -0.014]. Figure 2 [Figure 2: see original paper] illustrates these two moderating effects: the gene moderates the path from stress to healthy eating intention, with the effect of stress on intention being larger in the AA genotype (interaction, solid slope steeper than dashed slope); action control moderates the path from healthy eating intention to healthy eating behavior, with individuals having higher action control scores showing more healthy eating behavior (main effect of action control, dashed line higher than solid line) and less influence of dietary intention on behavior (interaction, dashed slope less steep than solid slope).

4. Discussion

4.1 Interpretation of Key Findings

The purpose of this study was to integrate HAPA with vagal nervous system dominance theory to explore the mechanisms by which stress, genes, and action control influence health behavior. Results from 14,675 Han Chinese adults supported a mediation model where stress affects healthy eating behavior through its impact on healthy eating intention. In the motivational phase of the health action process model, the CSF3R gene moderated the relationship between stress and healthy eating intention. For AA allele carriers (hypothesized to correspond to trophotropic type), there was a significant negative correlation between stress and healthy eating, while for G allele carriers (hypothesized to correspond to ergotropic type), this correlation was smaller. In the volitional phase of the health action process model, action control moderated the path from healthy eating intention to healthy eating behavior: individuals with higher action control scores exhibited more healthy eating behaviors that were less influenced by dietary intentions. All results passed split-half cross-validation.

Regarding the moderating effect of genes, consistent with other studies (Krueger & Chang, 2008; van der Zwaluw et al., 2009; van Strien et al., 2010), we found evidence supporting gene-environment ($G \times E$) interactions. When combined with a risk genotype (CSF3R AA homozygote), an adverse environment (high stress) poses higher risk for unhealthy eating. Notably, both AA genotype and G carriers showed negative relationships between stress and healthy eating intention, consistent with most previous research in meta-analyses (Hill et al., 2021): higher stress predicted lower healthy eating intention. Importantly, this study found that the gene only moderated the stage from stress to intention, with no significant moderating effect found on the latter stage from intention to behavior, which aligns with barriers often discussed in the volitional phase of HAPA. Translating health intentions into behavior requires crossing many obstacles through planning and behavioral control, and genes typically have small effect sizes that make it difficult to influence this stage.

Focusing on CSF3R, a gene affecting cytokine receptor expression that is closely associated with chronic psychological stress responses (Kawai et al., 2007; Le Niculescu et al., 2011), this study applied HAPA theory and vagal dominance theory to eating under stress. Results partially explained individual differences in how stress hinders healthy eating at the genetic level. It should be noted that, as is typical for individual difference variables, genetic effect sizes were small in this study, so results should be generalized with caution. This study hopes to use genes as a starting point for an individualized model of stress impact on health behavior, with future research incorporating more and more effective individual difference factors at physiological, behavioral, family, and social levels.

For the moderating effect of action control, although this study supported action control's moderating role between healthy eating intention and behavior, unlike

traditional HAPA predictions, high levels of action control primarily enhanced healthy eating behavior rather than bridging the gap between intention and behavior. Considering the entire process from stress to intention to behavior, individuals with high action control showed less negative impact of stress on healthy eating behavior than those with low action control.

The user wants me to translate a specific section of a Chinese academic paper. The section is “### 4.2 Theoretical Innovation and Application Value” .

Let me analyze the text:

1. **Content:** It's about theoretical innovation and practical value of a study that combines stress resilience theory, HAPA (Health Action Process Approach), and genetic individual differences to propose an individualized health action model for stress.
2. **Key elements to preserve:**
 - All math (there doesn't seem to be any explicit math in this section)
 - All citations like [?], ??, (??) (there are citations like (Feder et al., 2009), (Phoolka & Kaur, 2012), (Mullins et al., 2020), (O' Connor et al., 2015), (Adriaanse et al., 2009))
 - All figure/table markers (there's a reference to “Figure 1”)
 - Chinese characters must be removed - I see “思路” which needs to be translated
3. **Translation rules:**
 - Author names: Romanize using pinyin (but there are no Chinese author names in this section)
 - Journal names: Not applicable here
 - Institution names: Not applicable here
 - Technical terms: Use standard English equivalents
 - DO NOT leave any Chinese characters
4. **Structure:** Keep the same structure - the section heading and paragraphs.
5. **Style:** Academic tone, flowing readable prose, merge fragmented text, skip garbage text (none here), organize logically.

Let me go through the text paragraph by paragraph:

Paragraph 1: “Beyond expanding applications of previous theories, this study's main theoretical innovation combines stress resilience theory, HAPA, and genetic individual differences to propose an individualized health action model for stress. Within the HAPA framework, we found that stress primarily acts as a barrier to health behavior in the motivational phase, with genotype moderating stress effects in this phase, while action plans have strong main effects in the motivational phase and moderate the effect of intention on behavior in the

volitional phase. Based on these findings, we propose a new theory: an individualized model of stress impact on health behavior, which aims to fill theoretical gaps about the relationship between stress and unhealthy eating by combining HAPA and vagal dominance theory. This is the first study to incorporate the contextual factor of stress into a health behavior change model while considering the biological basis of genes. This breaks from the traditional focus of health behavior change models on individual behavioral levels, attempting to consider mechanisms affecting health behavior choices from both more fundamental physiological levels (genes) and more macroscopic environmental levels (stress).”

This looks good. I need to make sure it's fluent academic English. The term “vagal dominance theory” appears - I should keep that as is since it's a technical term. “HAPA” is an acronym that should be kept. “ergotropic-dominant” and “trophotropic-dominant” appear later - these are technical terms that should be preserved.

Paragraph 2: “Our proposed model includes not only stress exposure levels but also individual differences such as genotype in the healthy eating process. This development enriches the health behavior process model (Figure 1). Specifically, the individualized health action model for stress proposed in this study explains cases of negative health behavior outcomes following stress, thereby introducing person-environment interactions into health behavior process models. Moreover, the model provides detailed descriptions of the shape of the stress-health behavior relationship and its facilitating factors. Genotype may moderate risk and resilience at the individual level (Feder et al., 2009). Our model and empirical results provide a genetic basis for explaining the relationship between stress and health behavior, implying that genetic differences may partially explain why only some people develop unhealthy eating behaviors under stress exposure while others do not (Phoolka & Kaur, 2012).”

This is also clear. I need to preserve the citation format exactly as given.

Paragraph 3: “Additionally, this study tested the relationship between stress and healthy eating in a large national sample, yielding robust results with cross-validation, making the relationships between genes, stress, and healthy eating more solid. Our results validated the association between CSF3R-stress interactions and maintenance or disruption of healthy eating behavior, with this ability to maintain healthy eating after stress reflecting resilience to stress. Therefore, this study also provides important evidence for psychological resilience theory with a large sample.”

“CSF3R” is a gene name and should be kept as is. The term “psychological resilience theory” should be used.

Paragraph 4: “These results also have important practical implications. In recent years, as research on the relationship between genes and health has deepened, more people have begun to emphasize individualized healthy eating interventions. Different genotypes may have different dietary needs and responses, so

developing health plans based on individual genetic information can help people better maintain health. Currently, individualized healthy eating interventions based on genetic information are common (Mullins et al., 2020). On the basis of metabolic genes and nutrition-related genes, our results suggest adding vagal dominance genes as a reference for healthy eating plans. For ergotropic-dominant individuals, since the association between stress and unhealthy eating is weaker, stress-targeted interventions may not be effective; other intervention targets should be sought to help these individuals eat healthily, such as appropriately increasing protein and dietary fiber intake, encouraging fruit and vegetable consumption, and reducing high-sugar and high-fat foods. For trophotropic-dominant individuals, since stress level is associated with unhealthy eating, intervention targets could be reducing stress levels and improving eating habits. Additionally, a recent intervention developed by O' Connor et al. (2015) offers a promising approach. This method follows Adriaanse et al.'s (2009) intervention 思路 of replacing unhealthy snacks with healthy ones, requiring participants to imagine choosing healthy snack plans under pressure and implementing them, such as eating an apple when feeling worried. Randomized controlled experiments support the effectiveness of this intervention method: compared with control groups, experimental group participants no longer associated daily stress with unhealthy snacks subsequently and indeed ate more healthy snacks on stressful days. The purpose of this intervention is not to reduce stress-induced unhealthy eating itself but to help people plan ahead and increase their likelihood of choosing healthy foods under pressure, which is quite instructive."

Here I see the Chinese character “思路” in “intervention 思路”. I need to translate this. “思路” means “approach”, “idea”, “thinking”, or “methodology”. In this context, “intervention approach” or “intervention methodology” would be appropriate. The phrase is “Adriaanse et al.'s (2009) intervention 思路 of replacing unhealthy snacks with healthy ones”. So it should be “Adriaanse et al.'s (2009) intervention approach of replacing unhealthy snacks with healthy ones” or “the intervention approach of Adriaanse et al. (2009) for replacing unhealthy snacks with healthy ones”. I'll go with something natural like “the intervention approach developed by Adriaanse et al. (2009), which involves replacing unhealthy snacks with healthy ones”.

Let me check for any other Chinese characters. I see “路” and “思” were mentioned as detected issues, but in the actual text provided, I only see “思路”. Let me re-read carefully...No other Chinese characters are visible in the provided text.

Now I'll construct the final translation, ensuring: 1. All citations are preserved exactly 2. Figure 1 reference is preserved 3. Technical terms (HAPA, vagal dominance theory, ergotropic-dominant, trophotropic-dominant, CSF3R) are preserved 4. No Chinese characters remain 5. Academic tone is maintained 6. Prose is fluent and readable

The structure should be: - ### 4.2 Theoretical Innovation and Application Value - Paragraph 1 - Paragraph 2 - Paragraph 3 - Paragraph 4

I should make sure the translation flows well and doesn't sound like a literal translation. Let me refine some phrases:

“Beyond expanding applications of previous theories” -> “In addition to extending the application of existing theories” or “Beyond merely extending the application of previous theories”

“main theoretical innovation combines” -> “primary theoretical innovation lies in combining”

“to propose an individualized health action model for stress” -> “to propose a stress-specific individualized health action model”

“Within the HAPA framework, we found that stress primarily acts as a barrier to health behavior in the motivational phase” -> This is clear

“with genotype moderating stress effects in this phase” -> “with genotype moderating the effects of stress in this phase”

“while action plans have strong main effects in the motivational phase” -> “while action plans exert strong main effects in the motivational phase”

“and moderate the effect of intention on behavior in the volitional phase” -> “and moderate the effect of intention on behavior during the volitional phase”

“Based on these findings, we propose a new theory: an individualized model of stress impact on health behavior” -> “Based on these findings, we propose a novel theoretical model: an individualized model of stress's impact on health behavior”

“which aims to fill theoretical gaps about the relationship between stress and unhealthy eating by combining HAPA and vagal dominance theory” -> “which seeks to address theoretical gaps regarding the relationship between stress and unhealthy eating by integrating HAPA with vagal dominance theory”

“This is the first study to incorporate the contextual factor of stress into a health behavior change model while considering the biological basis of genes” -> “This represents the first study to incorporate stress as a contextual factor into a health behavior change model while simultaneously considering the biological basis of genetic factors”

“This breaks from the traditional focus of health behavior change models on individual behavioral levels” -> “This departs from the traditional focus of health behavior change models on individual behavioral levels alone”

“attempting to consider mechanisms affecting health behavior choices from both more fundamental physiological levels (genes) and more macroscopic environmental levels (stress)” -> “attempting to examine the mechanisms influencing health behavior choices from both more fundamental physiological levels (genes) and broader environmental levels (stress)”

Paragraph 2: “Our proposed model includes not only stress exposure levels but also individual differences such as genotype in the healthy eating process” -> “Our proposed model incorporates not only levels of stress exposure but also individual differences such as genotype within the healthy eating process”

“This development enriches the health behavior process model (Figure 1)” -> “This advancement enriches the health behavior process model (Figure 1)”

“Specifically, the individualized health action model for stress proposed in this study explains cases of negative health behavior outcomes following stress” -> “Specifically, the individualized health action model for stress proposed in this study accounts for instances of negative health behavior outcomes following stress exposure”

“thereby introducing person-environment interactions into health behavior process models” -> “thereby integrating person-environment interactions into health behavior process models”

“Moreover, the model provides detailed descriptions of the shape of the stress-health behavior relationship and its facilitating factors” -> “Furthermore, the model provides detailed descriptions of the form of the stress-health behavior relationship and its facilitating factors”

“Genotype may moderate risk and resilience at the individual level” -> This is clear

“Our model and empirical results provide a genetic basis for explaining the relationship between stress and health behavior” -> “Our model and empirical results provide a genetic foundation for explaining the relationship between stress and health behavior”

“implying that genetic differences may partially explain why only some people develop unhealthy eating behaviors under stress exposure while others do not” -> “suggesting that genetic differences may partially explain why only some individuals develop unhealthy eating behaviors under stress exposure while others do not”

Paragraph 3: “Additionally, this study tested the relationship between stress and healthy eating in a large national sample, yielding robust results with cross-validation, making the relationships between genes, stress, and healthy eating more solid” -> “Additionally, this study examined the relationship between stress and healthy eating within a large national sample, yielding robust results through cross-validation and thereby strengthening the associations among genes, stress, and healthy eating”

“Our results validated the association between CSF3R-stress interactions and maintenance or disruption of healthy eating behavior” -> “Our results confirmed the association between CSF3R-stress interactions and the maintenance or disruption of healthy eating behavior”

“with this ability to maintain healthy eating after stress reflecting resilience to stress” -> “with this capacity to maintain healthy eating following stress reflecting stress resilience”

“Therefore, this study also provides important evidence for psychological resilience theory with a large sample” -> “Therefore, this study also provides important evidence for psychological resilience theory based on a large sample”

Paragraph 4: “These results also have important practical implications” -> This is clear

“In recent years, as research on the relationship between genes and health has deepened, more people have begun to emphasize individualized healthy eating interventions” -> “In recent years, as research on the relationship between genes and health has advanced, there has been increasing emphasis on individualized healthy eating interventions”

“Different genotypes may have different dietary needs and responses, so developing health plans based on individual genetic information can help people better maintain health” -> “As different genotypes may entail different dietary needs and responses, developing health plans based on individual genetic information can help individuals better maintain their health”

“Currently, individualized healthy eating interventions based on genetic information are common” -> “Currently, individualized healthy eating interventions based on genetic information are commonplace”

“On the basis of metabolic genes and nutrition-related genes, our results suggest adding vagal dominance genes as a reference for healthy eating plans” -> “Building upon metabolic and nutrition-related genes, our results suggest incorporating vagal dominance genes as an additional reference for healthy eating plans”

“For ergotropic-dominant individuals, since the association between stress and unhealthy eating is weaker, stress-targeted interventions may not be### 4.3 Limitations and Future Directions

The current study has several limitations. First, our genetic results are based on Han Chinese, which may limit the generalizability of our findings. Further research on shared and non-shared genetic characteristics across different ethnic groups is needed, which may help integrate genetic-psychological trait association studies in the future. Additionally, due to limited research on CSF3R, the genetic effect size in this study was also small; future research needs to replicate our findings, such as by adding more candidate genes and using more diverse samples (Chabris et al., 2015). More research is also needed to establish the relationship between vagal dominance types and CSF3R genotypes.

Second, due to the limitations of self-reporting, these data are essentially correlational, and causal relationships between stress and eating behavior should

be inferred cautiously. It should be noted that our environmental stress variable was self-perceived stress level, which may differ from objective stress and already includes individual coping abilities (Cohen et al., 1983). Future research should consider more comprehensive assessments of stress variables, such as ecological momentary assessment (EMA), which allows investigation of complex psychological, behavioral, and physiological processes by repeatedly assessing behaviors (e.g., food intake), experiences (e.g., perceived stress), and physiological parameters multiple times per day in real life (Smyth & Stone, 2003). Given that eating is a health behavior that occurs multiple times daily (Dunton, 2018), EMA seems particularly suitable for studying the complex relationship between stress and food intake. It circumvents disadvantages of traditional methods (e.g., retrospective self-reports and laboratory tasks) by minimizing recall bias, maximizing ecological validity, and capturing intra-individual processes and changes across time and contexts (Feng & Shi, 2004; Ruf et al., 2022; Shiffman et al., 2008).

Moreover, although this study controlled for demographic variables such as sex, age, and education, BMI index was not included. Previous research has found that individuals with higher BMI tend to consume more food when under stress (O' Connor et al., 2008). Since more than half of our participants did not report BMI, we could not analyze this variable's effect on the model; future research should consider including BMI. Finally, although healthy eating is an important indicator of health behavior, it is only one aspect. Since the HAPA model is mainly used to explain the intention and action of health behavior, this study only measured healthy eating, and the healthy eating questionnaire used relatively crude indicators. Specifically, the model mentioned in the introduction primarily focuses on food energy—stress requires energy consumption to cope with potential threats, increasing high-sugar and high-fat diets and leading to obesity. However, when measuring healthy eating behavior, we followed previous healthy eating practices by only measuring fruit and vegetable consumption. Future research on stress and eating should include measurements of high-sugar and high-fat diets, consider dietary diversity and balance in measurements (e.g., eating only fruits and vegetables is not a balanced dietary structure and is also unhealthy), and consider other health behaviors such as exercise to further validate the proposed theoretical model. We expect that the phenomenon of stress affecting health behavior should be universal, while each health behavior may have the same or different moderating factors.

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Moderating effects of CSF3R and action control between stress and healthy eating: Preliminary evidence for an individual health action against stress model

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Abstract

A healthy diet is essential to maintaining a healthy lifestyle, yet many factors may hinder a healthy eating plan. Some studies have found that people tend to consume more unhealthy foods to cope with stress, but opposite findings also exist. Some people under stress may still maintain a healthy diet. The mechanisms by which people make different dietary choices under stress are not yet clear.

This study combined health behavior theories and vagal tone theory and proposed a gene-stress interaction model of dietary choice, arguing that different dietary choices under stress may be related to two types of vagal tone: trophotropic or ergotropic, representing tendencies toward regeneration/recovery or fight-or-flight preparation. CSF3R is a granulocyte colony-stimulating factor receptor closely associated with chronic psychological stress responses, and its different genotypes may lead to different stress responses, exhibiting the aforementioned trophotropic or ergotropic tendencies. Additionally, action control suggested by HAPA (Health Action Process Approach) may play a critical role in implementing healthy eating intentions into healthy eating behaviors.

A sample of 14,675 Chinese adults completed genotyping of saliva samples and questionnaires on perceived stress, action control, and healthy dietary intentions and behaviors. CSF3R was used as a candidate gene reflecting vagal tone due to its proven impact on stress response. Regression analysis tested the effect of stress on healthy dietary intentions and behaviors and the moderating effects of the CSF3R gene and action control.

Results found that stress predicted a significant reduction in healthy dietary intentions and a subsequent reduction in healthy dietary behaviors. The CSF3R gene rs4076431 and its linked loci rs4498771, rs10752589, and rs9660229 moderated the relationship between stress and healthy eating intentions, while action control moderated the relationship between healthy eating intentions and behaviors. For rs4076431, the negative relationship between stress and healthy eating intentions was stronger among individuals with the AA genotype (trophotropic)

than among G allele carriers (ergotropic). Higher action control scores were associated with more healthy eating behaviors and less indirect impact of stress on behavior.

These results supported the individual health action against stress model, which may be applied to healthy diet education and stress management. Individuals' stress levels reflecting environmental influence, dominance of vagal tone (or genotype), and action control reflecting individual physiological and psychological factors may all impact dietary choices.

Keywords: healthy eating; perceived stress; gene; vagal tone

Note: Figure translations are in progress. See original paper for figures.

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