

# Perceived Stress and Emotional Eating in Adolescence: Mediation Through Negative-Focused Cognitive Emotion Regulation and Reward Sensitivity

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## Research article

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1 **Perceived Stress and Emotional Eating in Adolescence: Mediation through**  
2 **Negative-focused Cognitive Emotion Regulation and Reward Sensitivity**

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23 **Abstract**

24 **Background:** There have been ambiguous findings on the empirical relationship  
25 between perceived stress and emotional eating. The mediating roles of  
26 negative-focused cognitive emotion regulation and reward sensitivity of these  
27 relationships, particularly for adolescents, are often overlooked. The objective of this  
28 study was to assess the association between perceived stress, negative-focused  
29 cognitive emotion regulation, reward sensitivity, and emotional eating in a sample of  
30 Chinese adolescents.

31 **Methods:** In this cross-sectional study, 562 adolescents were selected and evaluated  
32 based on perceived stress, negative-focused cognitive emotion regulation, reward  
33 sensitivity, and emotional eating. Model tests were conducted using serial multiple  
34 mediation analyses, controlling for sex, age, household income, and body mass index.

35 **Results:** Results showed that perceived stress directly affected adolescents' emotional  
36 eating. In addition, perceived stress indirectly affected emotional eating through  
37 negative-focused cognitive emotion regulation and reward sensitivity.

38 **Conclusions:** Findings support the hypothesis that perceived stress increases  
39 negative-focused cognitive emotion regulation, which increases reward sensitivity and  
40 thus increases emotional eating. Implications of these findings for preventive and  
41 therapeutic intervention are discussed, and future research recommendations are  
42 provided.

43 **Keywords:** Emotional eating, Adolescent, Stress, Cognitive emotion regulation,  
44 Reward sensitivity

45

## 46 **Background**

47 Emotional eating (EE), defined as eating in response to negative emotions [1], has  
48 been explained as a coping mechanism during moments of stress, whereby people try  
49 to ‘eat their troubles away’ with highly palatable foods which are rich in sugar, fat and  
50 calories [2]. However, emotional eating will not solve the stress origins, the stressor  
51 will remain and cause psychological discomfort [3, 4]. Thus, emotional eating creates  
52 a vicious circle. Emotional eating may lead to overweight or obesity over time and  
53 even evolve into an eating disorder (e.g., binge eating disorder), prediabetes and  
54 diabetes [2, 5]. These negative consequences emphasize the importance of obtaining  
55 further insight into emotional eating.

56 Stress arises when the demands being made on individuals or threats to their  
57 well-being exceed their available coping resources [6]. A meta-analysis concluded  
58 that stress was negatively associated with healthy eating behaviours in children aged  
59 13-18 years old [7]. In several studies, children’s and adolescents’ perceived stress  
60 have been associated with high scores on emotional eating [8, 9]. Vandewalle et al.  
61 [10] also found that daily stress is positively associated with daily fluctuations in  
62 scores on emotional eating. However, others observed exactly the opposite, they  
63 found individuals eat less or report no change during stressful situations compared to  
64 non-stressful situations [11-13]. According to the models of stress-induced eating [14,  
65 15], stress induces eating through physiological and psychological processes. Thus,  
66 the perspective that some factors mediated the effect of stress on emotional eating

67 may help to account for inconsistent empirical findings.

68 Cognitive emotion regulation (CER), or cognitive coping, generally refers to the  
69 cognitive way of managing the intake of emotionally arousing information during or  
70 after the experience of threatening or stressful events. Stress can affect cognitive  
71 emotion regulation [16], thus rendering individuals even more susceptible to  
72 emotional processes that can trigger unhealthy eating. Based on the long-term effects  
73 on affect, behaviour, and psychopathology, researchers suggest a classification in  
74 adaptive strategies and maladaptive strategies [17, 18]. CER strategies influence  
75 eating behaviour [19, 20]. Researchers hypothesize that individuals having difficulty  
76 regulating their emotions often turn to substances such as alcohol or food [2, 21].  
77 Studies in children and adolescents have revealed an association between maladaptive  
78 strategies and emotional eating [22-25]. This association is stronger when  
79 maladaptive strategies are used to deal with the stressor in comparison with the use of  
80 adaptive strategies [26]. These results suggest that a lack of adaptive strategies is not  
81 necessarily linked to emotional eating, but rather to the use of maladaptive strategies,  
82 whereas CER seems to mediate the stress-eating relationship [2, 19, 27]. The research  
83 on CER offers an interesting perspective on the problem of the relationship between  
84 stress and emotional eating.

85 Reward sensitivity (RS) is a psychobiological personality trait, referring to an  
86 individual's ability to experience pleasure or reward on exposure to appetitive stimuli  
87 [28]. RS increases from childhood to adulthood with a peak in adolescence, RS might  
88 thus play a substantive role in explaining adolescents' eating behaviours [29, 30]. For

89 example, De Cock et al. [31] found that RS was associated with snack and  
90 sugar- sweetened beverage consumption in adolescents aged 14–16 years, especially  
91 in girls. Stress makes people susceptible to substances that, via reward processing,  
92 motivate individuals to overconsume them [32]. Previous findings provide  
93 preliminary evidence that stress-reactive individuals show diminished RS under stress  
94 [33]. A review concluded that acute and chronic stress have dissociable effects on RS  
95 [34]. Specifically, acute stress is linked to an increase in incentive motivation and  
96 active coping behaviours, but chronic stress abolishes these behaviours and makes  
97 individuals become blunted with repeated stressors, reflected in a change in behaviour  
98 from active coping to learned helplessness and reduced RS. In addition, research on  
99 the determinants of emotional eating has also suggested the influence of individual  
100 traits such as sensitivity to food and reward [2]. Researchers reported that RS was  
101 related to emotional eating in adolescents [31] and adults [35]. Moreover, increased  
102 RS has been found to be associated with vulnerability to develop binge eating  
103 behaviour [36]. Several studies have revealed a positive, negative or no association  
104 between coping strategies and RS [37-40]. The research on CER and RS will enrich  
105 our understanding of stress-eating links.

106 Adolescence is a critical developmental period characterized by socioemotional and  
107 academic challenges where they are particularly vulnerable to detrimental  
108 consequences of stress. Simultaneously, they are gaining autonomy including with  
109 respect to food choices from parents. The purpose of this study to verify the mediating  
110 roles of negative-focused cognitive emotion regulation and reward sensitivity in the

111 synergic effect of the relationship between perceived stress and emotional eating. We  
112 hypothesized that negative-focused cognitive emotion regulation and reward  
113 sensitivity act as mediators between perceived stress and emotional eating among  
114 adolescents. Although these potentially associated constructs have been examined  
115 separately in the past, by incorporating both, this study will also allow for  
116 examination of the interrelationships between these variables. Examination of this  
117 issue may provide empirical foundations for prevention and intervention strategies  
118 tailored to concerns of adolescents.

119

## 120 **Methods**

### 121 **Sampling and data collection**

122 This was a cross-sectional study, conducted between October and November 2019,  
123 which enrolled 578 young adolescents aged between 12 and 15 years using a sample  
124 from Wuhan City, China (Central China). A total of five junior high schools were  
125 contacted randomly, of which two agreed to participate. We obtain informed consent  
126 from students and their legal guardians by sending letters to legal guardians through  
127 their schools. They had the choice to agree or to decline to participate in the study.  
128 Students who declined to fill the survey were excluded from this study.  
129 Questionnaires were self-administered and with no identification markers included in  
130 the data collection to ensure participant anonymity. Students needed approximately 20  
131 - 30 min to be complete the data collection. Participants were excluded for providing  
132 implausible responses (e.g., choose the last of all the options) to any of questionnaires

133 (n = 9), or failing to answer any of the following variables: sex, age, height, and  
134 household income (n = 7). Self-reported height and weight were used to calculate  
135 each participant's BMI (kg/m<sup>2</sup>). The final sample was comprised of 562 adolescents  
136 (12–15 years; mean age = 13.23 years, SD = 0.87; mean BMI = 19.00 kg/m<sup>2</sup>, SD =  
137 2.72; 51.60% males).

## 138 **Measures**

### 139 *Perceived Stress Scale (PSS)*

140 Perceived stress (PS) was measured using the 10-item PSS, a validated measure  
141 among adolescents [41]. The participants were asked how unpredictable,  
142 uncontrollable, and overloaded were the situations in the last month using a 5-point  
143 Likert scale from 0 (never) to 4 (very often). Total scores ranged from 0 to 40, and  
144 participants with higher scores had higher perceived stress levels. Internal consistency  
145 for the full 10-item scale was good in our sample (Cronbach's alpha = 0.90).

### 146 *The Dutch Eating Behaviour Questionnaire - child version (DEBQ - C)*

147 DEBQ - C was used as a measure of adolescents' emotional eating (i.e., desire to eat  
148 under different negative emotional states, such as irritated, depressed, lonely,  
149 frightened or disappointed). This is a unidimensional instrument with 13 items  
150 answered on a 5-point Likert scale from 1 (never) to 5 (very often), with higher scores  
151 reflecting more emotional eating. Studies have indicated the usefulness of the DEBQ -  
152 C in children and adolescents aged between 7 and 17 years [2]. In our study,  
153 Cronbach's alpha was 0.96.

### 154 *The Cognitive Emotion Regulation Questionnaire (CERQ)*

155 Negative-focused cognitive emotion regulation (NFCER) was measured using the 4  
156 maladaptive strategy subscales (self-blame, rumination, catastrophizing, and blaming  
157 others, 16-items) of the CERQ, which is a self-report assessment of an individual's  
158 cognitive emotion regulation strategies for stressful events or situation in general. The  
159 maladaptive strategy subscales are interpreted as “negatively focused cognitive  
160 emotion regulation”. Self-blame refers to thoughts of blaming yourself for what you  
161 have experienced. Rumination or focus on thought refers to thinking about the  
162 feelings and thoughts associated with the negative event. Catastrophizing refers to  
163 thoughts of explicitly emphasizing the terror of an experience. Blaming others refers  
164 to thoughts of putting the blame of what you have experienced on others. The CERQ  
165 can be administered to people aged 12 years and older [18]. Responders indicate their  
166 degree of agreement with a 5-point Likert scale ranging from 1 [(almost) never] to 5  
167 [(almost) always]. Higher total scores denote greater use of negative-focused  
168 cognitive strategies. Internal consistency in our study was good (0.89).

169 ***The Behavioural Activation Scales (BAS)***

170 Reward sensitivity was assessed with the BAS. These scales consisted of three  
171 subscales: reward responsiveness (5 items), drive (4 items) and fun seeking (4 items),  
172 namely the anticipation of and the positive response toward a reward, the persistence  
173 to obtain goals, and the willingness to seek out and spontaneously approach  
174 potentially rewarding experiences. All items are to be answered on a 4-point scale  
175 from 1 (totally disagree) to 4 (totally agree). Higher total scores indicate higher levels  
176 of the reward sensitivity. The scale is a valid measurement of RS in children and

177 adolescents [28]. In our sample the Cronbach's alpha was assessed as good for BAS  
178 (0.85).

### 179 **Statistical analysis**

180 Analyses were performed using SPSS version 25.0. Descriptive analysis,  
181 independent-samples T-test and one-way analysis of variance (ANOVA) were used to  
182 describe and compare the demographic data (sex, age, household income, and BMI)  
183 and questionnaires' scores. To yield standardized coefficients, all variables were  
184 converted to z-scores prior to analysis. Pearson's correlations were used to examine  
185 associations between study variables. To test the significance of the multiple-mediator  
186 model in this study, we adopted the model 6 of PROCESS v2.16 for SPSS provided  
187 by Hayes [42]. This approach was based on ordinary least-squares regression and the  
188 bootstrap method. Compared with the causal steps approach or the Sobel test, Hayes  
189 considered bootstrapping as the most powerful approach of assessment of indirect  
190 effects, as it was free from assumptions regarding the shape of the sampling  
191 distribution of the indirect effect and also had better control on type I errors. Hayes  
192 recommended 10000 bootstrap bias-corrected 95% confidence intervals (CI) to be  
193 used for mediation analyses in the test from the Serial-Multiple Mediation Model 6,  
194 and if they did not contain zero, they were considered significant [43]. PROCESS  
195 macro was performed using one independent variable (perceived stress), two  
196 mediators (negative-focused cognitive emotion regulation and reward sensitivity), and  
197 one dependent variable (emotional eating). Furthermore, both the direct and the total  
198 effect were tested. The serial mediation process estimated three specific indirect

199 effects from perceived stress to emotional eating: (a) the indirect path via  
200 negative-focused cognitive emotion regulation (PS → NFCER → EE); (b) the indirect  
201 path via reward sensitivity (PS → RS → EE); and (c) the indirect path via  
202 negative-focused cognitive emotion regulation to reward sensitivity (PS → NFCER  
203 →RS → EE). Finally, sex, age, household income, and BMI were treated as  
204 covariates, and all covariates were controlled for at the level of both the mediator and  
205 the outcome.

206 All variables were measured by self-report questionnaires so there might be the  
207 problem of common method variance. The Harman single factor test showed that 9  
208 factors were extracted, with the largest one accounting for 24.047% of the total  
209 variance, indicating that common method variance is not likely to influence our  
210 results [44].

211

## 212 **Results**

### 213 **Preliminary Analyses**

214 Tables 1 categorical participant demographics, respectively, presented by gender  
215 group. As shown in Tables 1, significant mean group (male vs. female) differences  
216 emerged for perceived stress, negative-focused cognitive emotion regulation and  
217 emotional eating. One-way analysis of variance showed there were no significant  
218 differences in household income related to age ( $F = 1.473$ ,  $p = 0.221$ ), perceived stress  
219 ( $F = 1.568$ ,  $p = 0.196$ ), negative-focused cognitive emotion regulation ( $F = 1.023$ ,  $p =$   
220  $0.382$ ), reward sensitivity ( $F = 0.854$ ,  $p = 0.465$ ), and emotional eating ( $F = 0.980$ ,  $p =$

221 0.402). Welch's ANOVA showed there were significant differences in household  
 222 income related to BMI ( $F = 46.724$ ,  $p = 0.000$ ). Post hoc tests (Games-Howell)  
 223 indicated that <30000 CNY household income participants had lower BMI (mean  
 224 BMI =  $17.03 \text{ kg/m}^2$ ,  $SD = 1.61$ ) compared to other participants, and  $\geq 100000$  CNY  
 225 household income participants had lower BMI (mean BMI =  $18.17 \text{ kg/m}^2$ ,  $SD = 2.36$ )  
 226 compared to 30000-49999 CNY and 50000-99999 CNY household income  
 227 participants, whereas no difference was found between 30000-49999 CNY (mean  
 228 BMI =  $20.02 \text{ kg/m}^2$ ,  $SD = 3.40$ ) and 50000-99999 CNY (mean BMI =  $19.93 \text{ kg/m}^2$ ,  
 229  $SD = 2.43$ ) household income participants.

230 **Table 1 Demographic Characteristics and Study Variables for Study**  
 231 **Participants**

Characteristics	Male (n = 290)		Female (n = 272)		t	p	Total (n = 562)	
	M	SD	M	SD			M	SD
Age, years	13.280	0.877	13.190	0.858	1.253	0.211	13.230	0.868
BMI, $\text{kg/m}^2$	19.101	2.936	18.885	2.467	0.943	0.346	18.996	2.719
Perceived stress	7.990	7.556	12.670	8.659	-6.848	0.000	10.250	8.434
Negative-focused cognitive emotion regulation	33.910	11.251	36.590	10.773	-2.878	0.004	35.210	11.094
Reward sensitivity	36.260	6.872	37.050	7.168	-1.338	0.181	36.640	7.022
Emotional eating	23.070	12.297	26.720	13.271	-3.386	0.001	24.840	12.897

Characteristics	Male (n = 290)		Female (n = 272)		Total (n = 562)	
	n	%	n	%	n	%
Household income						
<30000 CNY	32	11.0	27	9.9	59	10.5
30000-49999 CNY	44	15.2	41	15.1	85	15.1
50000-99999 CNY	113	39.0	99	36.4	212	37.7
$\geq 100000$ CNY	101	34.8	105	38.6	206	36.7

232

233 **Correlation analyses**

234 Pearson correlation coefficients showed that age was negatively related to perceived  
 235 stress ( $r = -0.107$ ,  $p = 0.011$ ) and emotional eating ( $r = -0.111$ ,  $p = 0.008$ ), and  
 236 positively related to reward sensitivity ( $r = 0.122$ ,  $p = 0.004$ ), yet no significant  
 237 correlation between age and negative-focused cognitive emotion regulation ( $r = 0.011$ ,  
 238  $p = 0.797$ ), and BMI ( $r = 0.070$ ,  $p = 0.098$ ). Also, there were no significant correlation  
 239 between BMI and perceived stress ( $r = 0.035$ ,  $p = 0.403$ ), emotional eating ( $r = 0.027$ ,  
 240  $p = 0.529$ ), negative-focused cognitive emotion regulation ( $r = 0.001$ ,  $p = 0.974$ ) and  
 241 reward sensitivity ( $r = 0.072$ ,  $p = 0.087$ ).

242 The correlations between the four study variables are shown in Table 2. Perceived  
 243 stress was positively related to emotional eating, negative-focused cognitive emotion  
 244 regulation and reward sensitivity. These bivariate correlations support the following  
 245 mediation analyses. In addition, there were significant correlation between emotional  
 246 eating and 4 maladaptive strategies of cognitive emotion regulation (self-blame,  $r =$   
 247  $0.176$ ; rumination,  $r = 0.180$ ; catastrophizing,  $r = 0.221$ ; blaming others,  $r = 0.206$ ;  $p =$   
 248  $0.000$ ).

249 **Table 2 Correlations between perceived stress, negative-focused cognitive**  
 250 **emotion regulation, reward sensitivity, and emotional eating**

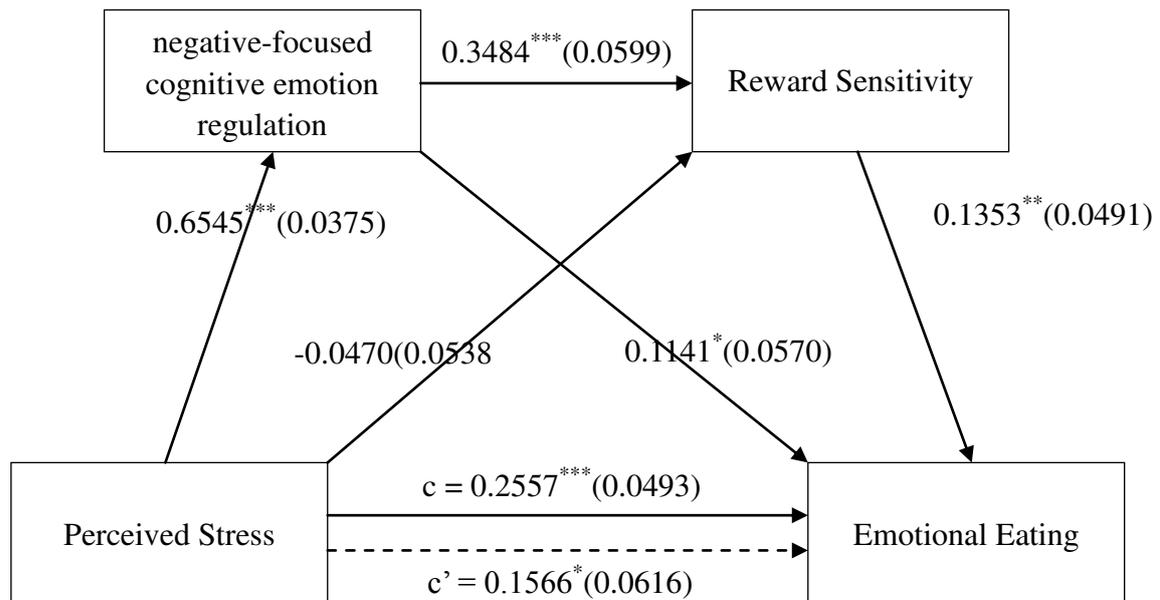
Variable	1	2	3	4
1. Perceived stress	1.000			
2. Negative-focused cognitive emotion regulation	0.629 <sup>***</sup>	1.000		
3. Reward sensitivity	0.176 <sup>***</sup>	0.326 <sup>***</sup>	1.000	
4. Emotional eating	0.282 <sup>***</sup>	0.262 <sup>***</sup>	0.194 <sup>***</sup>	1.000

Note. \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

251

## 252 **Mediation of the Relationship Between Perceived Stress and Emotional Eating**

253 As shown in Fig. 1, the total effect ( $\beta = 0.2557$ ,  $p = 0.0000$ , 95% CI = [0.1589,  
254 0.3526]) from perceived stress to emotional eating was at a significant level (Step 1).  
255 Moreover, the direct paths from perceived stress to negative-focused cognitive  
256 emotion regulation was significant ( $\beta = 0.6545$ ,  $p = 0.0000$ , 95% CI = [0.5809,  
257 0.7281]). However, the direct paths from perceived stress to reward sensitivity was  
258 insignificant ( $\beta = -0.0470$ ,  $p = 0.3824$ , 95% CI = [-0.1527, 0.0586]). Meanwhile, the  
259 paths from the first mediator (negative-focused cognitive emotion regulation) to the  
260 second mediator (reward sensitivity) were also significant ( $\beta = 0.3484$ ,  $p = 0.0000$ , 95%  
261 CI = [0.2308, 0.4660]) (Step 2). The paths from the mediators, namely,  
262 negative-focused cognitive emotion regulation ( $\beta = 0.1141$ ,  $p = 0.0456$ , 95% CI =  
263 [0.0022, 0.2260]) and reward sensitivity ( $\beta = 0.1353$ ,  $p = 0.0061$ , 95% CI = [0.0388,  
264 0.2318]), to emotional eating were significant (Step 3). The direct path from  
265 perceived stress to emotional eating was significant ( $\beta = 0.1566$ ,  $p = 0.0114$ , 95% CI  
266 = [0.0355, 0.2777]) (Step 4). Moreover, the mediating variables (negative-focused  
267 cognitive emotion regulation and reward sensitivity) were observed to exert a  
268 mediating effect on the relationship between perceived stress and emotional eating.



269

270 \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001

271 **Fig. 1** The serial multiple mediation model of the present study

272

273 Table 3 shows the direct and indirect path estimates and bias-corrected CIs while  
 274 controlling for sex, age, household income, and BMI. As shown in the table, the total  
 275 indirect effect (i.e., the difference between total effect and direct effect) of perceived  
 276 stress through negative-focused cognitive emotion regulation and reward sensitivity  
 277 on emotional eating was significant (b = 0.0992, 95% CI = [0.0303, 0.1738]). The  
 278 single mediation of negative-focused cognitive emotion regulation, and the multiple  
 279 serial mediations of negative-focused cognitive emotion regulation and reward  
 280 sensitivity were significant in the tested model, but the single mediation of reward  
 281 sensitivity in the relationship between perceived stress and emotional eating was  
 282 insignificant in the tested model.

283 **Table 3 Bootstrapping indirect effects and 95% confidence intervals (CI) for the**  
 284 **final mediational model**

Number	Model pathways	Point estimates $\beta$	95% CI	
			Lower	Upper
1	Total Indirect Effect	0.0992	0.0303	0.1738
2	PS $\rightarrow$ NFCER $\rightarrow$ EE	0.0747	0.0025	0.1495
3	PS $\rightarrow$ NFCER $\rightarrow$ RS $\rightarrow$ EE	0.0309	0.0099	0.0605
4	PS $\rightarrow$ RS $\rightarrow$ EE	-0.0064	-0.0272	0.0063

*Note:* 95% CIs are bias corrected; bootstrap resamples = 10000. PS = perceived stress; EE = emotional eating; NFCER = negative-focused cognitive emotion regulation; RS = reward sensitivity.

285

## 286 **Discussion**

287 This study aimed to examine the relationships between perceived stress and emotional  
 288 eating among adolescents. Results indicated that for adolescents, increased perceived  
 289 stress was directly associated with increased emotional eating via a pathway from  
 290 higher negative-focused cognitive emotion regulation to higher reward sensitivity.

291 In line with prior studies, adolescents of higher perceived stress reported more  
 292 emotional eating behaviours [2, 8, 9], and perceived stress had a significant direct  
 293 effect and a significant total effect on emotional eating. People who live with chronic  
 294 stress often cope with stressors by engaging in unhealthy behaviours, such as smoking,  
 295 drug and alcohol abuse, and overeating. Because, eating more comfort food reduces  
 296 anxiety by reduce activity in the hypothalamo-pituitary-adrenal axis [45]. People who  
 297 exhibit emotional eating, derived from Kaplan's psychosomatic theory of obesity [27],  
 298 tend to overeat in order to reduce discomfort. Emotional eating may be learned [46].  
 299 In the classical conditioning framework, food intake is the unconditioned stimulus,  
 300 which is paired with unconditioned responses such as salivation and a desire to eat.  
 301 Over time, if perceived stress is systematically paired with food intake, it may become  
 302 a conditioned stimulus that can produce conditioned responses such as an increased

303 desire to eat. In the operant-conditioning framework, successfully reducing negative  
304 affect through food intake is considered to reinforce emotional eating. Over time, if  
305 perceived stress is systematically paired with food intake, people may become  
306 conditioned to experience an increased desire to eat. Thus, the more stress a person  
307 perceived, the more emotional eating behaviours.

308 Serial multiple mediation analyses indicated that emotional eating may occur based  
309 on indirect associations made between perceived stress and emotional eating, not only  
310 a direct consequence of perceived stress. There was a significant indirect effect  
311 between perceived stress and emotional eating behaviour that was mediated by  
312 negative-focused cognitive emotion regulation. One theory is that bingeing occurs as  
313 part of an attempt to escape from negative self-awareness. Attention is focused on the  
314 immediate stimulus environment and away from more meaningful levels of cognition,  
315 allowing the individual to avoid dealing with ego-threatening information [19]. This  
316 narrowing of attention disengages normal inhibitions against eating and fosters an  
317 uncritical acceptance of irrational beliefs and thoughts. As maladaptive strategies fail  
318 to diminish the negative effect from stress, the adolescent may consequently turn to  
319 food as comfort. Thus, during stressful situations, the more negative-focused  
320 cognitive emotion regulation an adolescent had, the more emotional eating behaviours  
321 he or she had.

322 There was no significant indirect effect between perceived stress and emotional  
323 eating behaviour that was mediated by reward sensitivity, while reward sensitivity had  
324 a significant direct effect on emotional eating. Previous research found that stress

325 would increase or diminish reward sensitivity [34]. However, we didn't find that  
326 stress had a significant direct effect on reward sensitivity. It may be due to individual  
327 differences of reward sensitivity influenced by genetic and environmental factors [47];  
328 no significant effect was found in the limited sample size. It also suggested that some  
329 factors mediated the effect of stress on reward sensitivity, such as cognitive emotion  
330 regulation.

331 Furthermore, this study found that negative-focused cognitive emotion regulation  
332 and reward sensitivity significantly partially mediated the effect of perceived stress on  
333 emotional eating. The results indicated that adolescents had an increased tendency to  
334 approach rewarding stimuli such as highly palatable foods and then had more  
335 emotional eating behaviours, when they had more difficulties in coping with  
336 perceived stress. According to resource depletion theory [48], self's capacity for active  
337 volition is limited, all acts of self-control rely on the same limited resource. As such,  
338 the use of these resources for an initial act of self-control would reduce the resources  
339 available for a subsequent self-control behaviour. According to the theory of stress  
340 induced eating [27], the cognitive load of coping with a stressor may overwhelm  
341 self-regulatory resources so that people focus on eating rather than focusing on the  
342 stressor. Negative-focused cognitive emotion regulation consumed more resources;  
343 individuals thus failed to control their cravings for reward stimuli and eating  
344 behaviour properly after negative-focused cognitive emotion regulation. If cognitive  
345 emotion regulation fails, self-regulation in other areas, like control over eating  
346 behaviours, can fail as well [49]. Our study suggested that reducing negative-focused

347 cognitive emotion regulation is necessary for the regulation of emotional eating.  
348 Therefore, the emotional eating of adolescents can be reduced by reducing  
349 maladaptive strategies. For example, cognitive emotion regulation could be improved  
350 by cognitive behaviour therapy and mindfulness-based therapy.

351 This study also showed that girls perceived more stress, used more  
352 negative-focused cognitive emotion regulation, and reported more emotional eating  
353 than boys. This could be because girls are under more pressure from school  
354 performance, relationships and looks than boys. In this study, age was negatively  
355 related to perceived stress and emotional eating. Younger adolescents just come to a  
356 new junior high school and face challenges in academic and extracurricular areas, and  
357 they need some time to adjusted to the new environment, thus they perceived more  
358 stress. Consistent with previous studies, age was positively related to reward  
359 sensitivity, because reward sensitivity increases from childhood to adulthood [29, 30].

360 It is also important to note several limitations. First, all participants come from one  
361 city; thus, the rates of perceived stress and emotional eating reported here should not  
362 be considered representative of different subgroups. To maximize the generalizability  
363 of future studies, randomized sampling should be performed at many sites.  
364 Furthermore, the measures utilized here all rely on self-report and may be subject to  
365 response bias. To reduce the impact of subjectivity, multiple methods should be  
366 developed and used for assessment [50]. However, self-report measures are  
367 commonly used to assess stress, cognitive emotion regulation, reward sensitivity, and  
368 eating behaviour, and the validity of the study instruments has been well established.

369 Finally, no causal conclusions can be drawn because of the cross-sectional nature of  
370 the study. Nevertheless, these findings offer a first assessment of the mediating roles  
371 of reward sensitivity and negative-focused cognitive emotion regulation in the  
372 relationship between perceived stress and emotional eating in adolescence, utilizing  
373 validated measures of study variables. Findings suggest a need for further research in  
374 this area. Longitudinal studies should be undertaken to better assess whether reducing  
375 negative-focused cognitive emotion regulation has a preventative or ameliorative role  
376 in emotional eating and which maladaptive or adaptive cognitive strategies affects the  
377 relationship between perceived stress and emotional eating. Future work should also  
378 assess the influence of perceived stress on emotional eating in different demographics,  
379 such as people in late adolescence and early adulthood. As our results only explained  
380 part of the association between perceived stress and emotional eating, future research  
381 should focus on other factors such as parental behaviours, peer influence, and social  
382 media in relation to emotional eating.

383

## 384 **Conclusions**

385 In summary, this study extended insights into the complex interactions among the  
386 perceived stress, negative-focused cognitive emotion regulation, reward sensitivity,  
387 and emotional eating of Chinese adolescents. The important path from perceived  
388 stress to negative-focused cognitive emotion regulation to reward sensitivity to  
389 emotional eating determines the internal mechanism between perceived stress and  
390 emotional eating. The results of the current study can provide valuable guidance in

391 implementing psychological interventions to reduce emotional eating and improve  
392 eating behaviours of adolescents. Avoiding stress can be used as a preventive therapy  
393 to help such adolescents to reduce emotional eating. It can also be used as an active  
394 therapy to help them manipulate the impact of negative-focused cognitive emotion  
395 regulation and reward sensitivity, thereby reduce emotional eating.

396

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400

### 401 **Authors' contributions**

402 Xia Xu and Jiaai Huang conceived and designed the study. Jiaai Huang, Yuanjie Wang  
403 and Na Ye collected and interpreted the data. Jiaai Huang wrote the first draft of the  
404 manuscript. Jiaai Huang and Xia Xu modified the manuscript. Yuanjie Wang and Na  
405 Ye reviewed the manuscript. All authors critically revised the manuscript and  
406 approved the final version.

407

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413

414 **Availability of data and materials**

415 The datasets generated during and analysed during the current study are available in  
416 the [Open Science Framework] repository, [<https://osf.io/r74yh>].

417

418 **Ethics approval and consent to participate**

419 The research protocol was approved by the Ethics Committee of Wuhan Sports  
420 University.

421

422 **Consent to publication**

423 Not applicable.

424

425 **Competing interests**

426 The authors declare that they have no competing interests.

427

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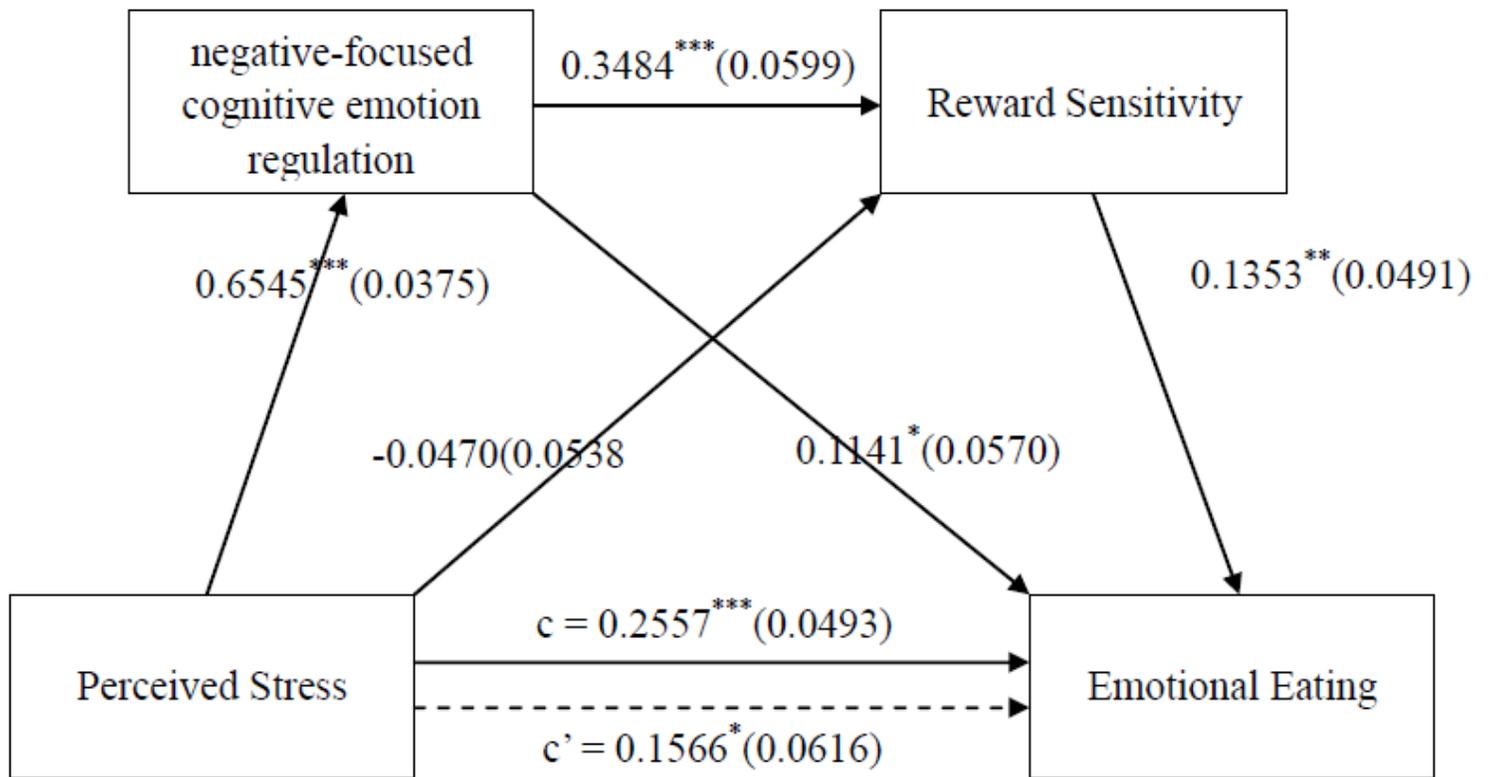
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569

570

## Figures



\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

Figure 1

The serial multiple mediation model of the present study