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Exploring the relationship between food insecurity, exercise addiction, and muscularity-oriented eating behavior: a moderated mediation analysis of muscle dysmorphia and resilience

Siwahdol Chaimano[1], Krit Rudeejaroonrung[1,2], Chih-Ting Lee[3*], Chung-Ying Lin[4,5], Carol Strong[6], Yee-How Say[7], Ai Kah Ng[8], Chin Xuan Tan[9], Poh Ying Lim[10], Bagas Suryo Bintoro[11], Azizuddin Khan[12] and Meng-Che Tsai[1,13,14*]

Abstract

Background Evidence suggests that food insecurity (FI) is associated with body image concerns (e.g., muscle dysmorphia; MD), behavioral addictions, and disordered eating behaviors. This study aimed to investigate whether MD mediates the association between FI and risks of exercise addiction (EA) and muscularity-oriented eating (MOE), focusing on the moderating role of resilience.

Methods A total of 1,500 young Taiwanese young adults (*Mage* = 22.2 years, 38.3% males) completed the online survey. Structural equation modeling was used to examine the relationships among the variables of interest. The significance of the moderated mediation model was assessed using bootstrapping.

Results Results found that FI was indirectly associated with increased risks of EA (β = 0.431, [0.312, 0.563]) and MOE (β = 2.3, [1.707, 2.887]) through MD. A gender difference was noted, as FI was more strongly associated with the risk of MOE in males and EA in females. Furthermore, resilience moderated the meditation relationship linking FI to EA (index of moderated mediation = 0.066, [0.032, 0.105]) and MOE (index of moderated mediation = 0.341, [0.163, 0.528]).

Conclusions FI is potentially associated with behavioral addiction and disordered eating psychopathology through body image concerns. Strengthening resilience may help attenuate these adverse effects in young adults with food security issues.

Plain English summary

Not having reliable access to enough food, known as food insecurity, can affect mental health and behavior in young people. Based on a survey of 1500 young adults in Taiwan, food insecurity was linked to greater concern

*Correspondence:
Chih-Ting Lee
christina.unicorn@gmail.com
Meng-Che Tsai
mengchets@gs.ncku.edu.tw

Full list of author information is available at the end of the article

about muscular appearance, which in turn increased the risk of uncontrolled excessive exercise and muscularity-focused eating behaviors. Gender differences included that food insecurity was more strongly linked to muscularity-focused eating for men and uncontrolled excessive exercise for women. Importantly, higher levels of resilience, defined as the ability to cope with stress and adversity, reduced the strength of these associations. Overall, the results suggest that young people experiencing food insecurity may be more vulnerable to harmful body image concerns and related behaviors. Strengthening resilience and providing resources to address food insecurity may help protect against these adverse effects.

Keywords Food insecurity, Muscle dysmorphia, Exercise addiction, Muscularity-oriented eating, Resilience

Introduction

Food insecurity (FI) refers to a state where individuals or households lack consistent access to food for an active and healthy life [1]. In 2022, an estimated 2.4 billion people worldwide experienced moderate to severe FI, with 9.2% of the global population suffering from chronic hunger [2]. In Taiwan, a recent study reported that 40.5% to 51.9% of adolescents and children from lower socioeconomic status backgrounds face FI [3]. FI has been extensively implicated in the development of physical, mental, and behavioral health problems, such as obesity [4], diabetes [5], depression [6], reduced cognitive functioning [7], and even substance use [8]. Regarding eating behaviors, emerging evidence consistently indicates that FI is associated with higher levels of overall eating disorder pathology, binge eating, compensatory behaviors, binge-eating disorder, and bulimia nervosa [9]. In Taiwan, the prevalence of eating disorders is lower compared to Western countries, but it has been increasing rapidly among Taiwanese adults [10]. Amongst both immigrant and native Taiwanese adolescents, the prevalence is approximately 11.4% [11]. This association is likely explained by a "feast-or-famine" cycle, in which food intake varies according to fluctuations in food availability [9]. Similarly, individuals with FI may become more vulnerable to weight control behaviors, such as dietary restriction or excessive exercise, during and following periods of food scarcity [12].

Exercise addiction (EA) is a behavioral addiction characterized by excessive training, loss of self-control, over-exercise behaviors, and potential contributions to physical and psychosocial problems [13]. Although EA is not classified as a Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Text Revision (DSM-5-TR) diagnosis, it has been conceptualized as a behavioral addiction [14]. Though the link between FI and EA remains underexplored, FI has been shown to be associated with addictive behaviors, such as increased substance use and food addiction [15, 16]. Evidence regarding the relationship between FI and exercise behaviors is comparatively limited and inconsistent. Individuals with FI tended to have lower physical activity levels [17, 18] but still had a non-significant trend of more vigorous exercise patterns and longer weekly exercise duration than food-secure counterparts [19]. FI may increase the neurobiological activity of the neural reward system, which regulates feelings of pleasure, motivation, and reinforcement learning. Alterations in neural reward circuits, such as the mesocorticolimbic pathway or neurotransmitters like dopamine, contribute to changes in pleasure and motivation. Previous studies suggest that substance use and certain behaviors similarly enhance this neural pathway's activity and learning, resulting in pleasure when substances are consumed or behaviors are experienced [18]. During periods of food availability, individuals with FI may experience pleasure from food, and FI may enhance reward sensitivity, thereby promoting addictive behaviors [17]. Despite this potential neurobiological link, the empirical association between FI and EA remains under-researched.

Muscularity-oriented eating (MOE) is a maladaptive eating behavior driven by the internal desire to attain a muscular physique [20]. It is suggested that MOE is a form of disordered eating psychopathology that is related to weight and body image concerns [21]. Individuals with MOE behaviors often use specific eating strategies, such as bulking and cutting, to achieve their muscular ideal [22]. During the bulking phase, they consume excessive protein to gain strength and muscle mass. In contrast, the cutting phase involves fasting, skipping meals, or restricting food intake to reduce fat and enhance leanness. Moreover, some individuals may also use supplements to aid in fatty acid metabolism or muscle boosting or resort to steroid usage [23], leading to unhealthy and harmful lifestyles [24]. How FI is related to MOE is, however, not fully explored yet, despite its association with increased disordered eating psychopathology, such as binge eating disorder [25], bulimia nervosa [26], and self-control eating [27]. While food-insecure individuals are likely to consume affordable foods with high-calorie diets, such foods typically contain high fat and sugar but less protein and nutrients necessary for muscle growth and physical development [28], contributing to lower muscle strength in food-insecure individuals [29]. Thus, whether this link can be translated to the relationship between FI and MOR requires more empirical research.

Muscle dysmorphia (MD) is a psychopathological condition characterized by an obsession with perceived

physical flaws, particularly a lack of muscularity. This condition is associated with eating disorders [30], obsessive-compulsive disorder [31], and addictive behaviors to maintain body image [32]. A recent study revealed an association between FI and MD symptomatology, suggesting that FI increases symptoms of MD among Canadian populations [33], especially in domains of functional impairment and appearance intolerance. Furthermore, MD is usually considered a core component of EA due to their similarities in behavioral addictive patterns [34]. Therefore, it is plausible that MD can be a critical mediator linking FI to EA and MOE. That said, those with FI may experience stress and lower self-esteem due to food scarcity, contributing to MD development, thus shifting attitudes and behaviors toward EA and MOE as coping strategies to gain thinner or muscular body ideals.

Gender differences have been observed in various human behaviors due to biological differences and differing social roles and expectations. Previous studies indicate that female-headed households experience higher rates of FI than male-headed households [35, 36]. This disparity may reflect broader structural inequities, including gender-based differences in access to economic resources, employment opportunities, land ownership, and social protection systems [37]. Women very often face labor market disadvantages, lower wages, and greater caregiving responsibilities, which can constrain income generation and household food access. For instance, in agrarian societies, gender inequalities in barriers to education and employment opportunities and access to productive assets and agricultural inputs may further limit the returns women obtain from comparable resources, contributing to poorer food security outcomes in female-headed households [35]. In addition, FI is associated with higher body mass index (BMI) among women but not among men [38]. This gender-specific association may be partly explained by differences in genetic predisposition to adiposity, pregnancy-related weight changes, and coping strategies characterized by cyclical patterns of food restriction and overeating [38]. Women may be more likely to reduce their own food intake during periods of scarcity and compensate by overeating when food becomes available, while other household members maintain more stable levels of consumption [39]. However, associations between food insecurity and other cardiovascular health outcomes, including hypertension, high cholesterol, diabetes, and sedentary time, remain inconclusive. Tayie and Zizza reported a higher likelihood of dyslipidemia among food-insecure women [40], whereas Royer et al. found no gender differences in the associations between food insecurity and cardiovascular health outcomes [41]. Nonetheless, males seem more susceptible to EA [42] and MOE [43], and higher odds of MD were noted among males exhibiting greater self-reliance and stronger adherence to heterosexual masculine norms [33]. Additionally, social expectations dictate that males are more likely to be concerned about their muscles and masculine body, whereas females tend to focus on their leg appearance and leanness [44]. Therefore, gender is a pertinent issue that should be considered in our analysis.

To address the research gaps described above, this study aimed to investigate the complex relationship between FI, MD, EA, and MOE, where we hypothesized that FI is associated with EA and MOE via the mediation of MD. Further, if the relationship exists, it remains imperative to explore whether it can be modified by individual psychological traits (e.g., resilience) that can be leveraged to attenuate the adverse effects of FI on exercise and eating behaviors. Trait resilience, reflecting one's ability to counter environmental adversities and then make adaptations [45], has been extensively associated with decreased symptoms of eating disorders [46], emotional distress [47], and addiction problems [48]. A prior study also found that building resilience potentially reduced body image disturbance [49]. Based on the theoretical framework and empirical evidence reviewed above, we tested the following specific hypotheses:

H1: FI will be positively associated with EA and MOET.

H2: MD will mediate the relationship between FI and both EA and MOE.

H3: Resilience will moderate the direct effects of FI on EA and MOE, such that higher resilience will attenuate these associations.

H4: Resilience will moderate the indirect effects (through MD) of FI on EA and MOE.

H5: Gender will moderate the relationships examined in H1-H4, with males showing stronger associations between FI and MOE, and females showing stronger associations between FI and EA.

Materials and methods

Participants and procedure

Our cross-sectional data were obtained from 1,500 Taiwanese young adults aged between 20 and 25 years. Participants were excluded from this study if they declared acute and chronic neurological illnesses such as stroke, psychiatric disorders such as depression and schizophrenia, and functional as well as intellectual disabilities. At the beginning of the survey, participants were asked to self-report whether they had been diagnosed with any of these conditions. Those who indicated 'yes' were automatically prevented from continuing the survey. The recruitment process was conducted through an online survey, Google Forms, from July to December 2022, when COVID-19-related constraints had just been lifted. This research was advertised verbally and via social media platforms. Before starting the survey,

participants received detailed information and provided informed consent by selecting "consent to participate"; otherwise, the survey ended. They were informed about the study, and all provided informed consent, including the knowledge that they could exit the survey at any time. The survey took approximately 30 min, and participants received 100 NTD (New Taiwan Dollars) as compensation after completing all the items of interest in the Mandarin questionnaire. The study procedures were carried out in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the National Cheng Kung University Hospital (A-ER-110-571).

Measures

All questionnaires were administered in Mandarin Chinese. For measures lacking validated Mandarin versions, we used standardized translation and back-translation procedures. Specifically, two bilingual researchers independently translated the original English versions into Mandarin, and discrepancies were resolved through discussion. A third bilingual researcher, who was blind to the original English version, back-translated the Mandarin version into English. The research team then compared the back-translated version with the original to ensure semantic equivalence.

Measure of food insecurity

FI was measured by a single-item question assessing the level of food insecurity concern, which was based on this statement: *"In the past year, have you ever worried that you/yourself or your family had no money to buy food?"* The question was rated on a 4-point Likert scale, in which four options were available from "not worried at all (1)", "not worried (2)", "a little worried (3)", to "very worried (4)". Thus, higher scores indicate higher levels of FI concern among participants. Although this single-item measure primarily captures subjective concern about food affordability rather than actual food access or experiences of hunger, it offers a graded assessment of food insecurity on a 4-point scale. Previous research has indicated an acceptable performance of using a single FI question to assess the level of FI [8, 50].

Muscle dysmorphic disorder inventory

The Muscle Dysmorphic Disorder Inventory (MDDI) was employed to assess the presence of MD symptoms [51]. This inventory consists of a 13-item self-report questionnaire divided into three distinct subscales: Drive for Size (e.g., *"I think my body is too skinny/slender."*), Appearance Intolerance (e.g., *"I wear loose clothing so that people cannot see my body."*), and Functional Impairment (e.g., *"I cancel social activities with friends because of my workout/exercise schedule."*). Participants rate each item on a 5-point Likert scale, from "never" (1), "seldom" (2), "sometimes" (3), "usually" (4), to "always" (5), with higher scores indicating more pronounced MD symptoms, as documented by Hildebrandt et al. [52]. The MDDI has demonstrated robust psychometric properties to capture MD across various demographic groups [53, 54]. In our study, the MDDI exhibited satisfactory internal reliability (Cronbach's $\alpha = 0.792$).

Exercise addiction inventory

The Exercise Addiction Inventory (EAI) was used to assess thoughts, attitudes, and behaviors related to EA [55, 56]. This 6-item self-report questionnaire comprises six components, which are salience (*"Exercise is the most important thing in my life."*), withdrawal symptoms (*"If I have to miss an exercise session, I feel moody and irritable."*), relapse (*"If I cut down the amount of exercise I do, and then start again, I always end up exercising as often as I did before."*), tolerance (*"Over time, I have increased the amount of exercise I do in a day."*), mood modification (*"I use exercise as a way of changing my mood."*), and conflict (*"Conflicts have arisen between me and my family and/or my partner about the amount of exercise I do."*). Participants rated each component on a 5-point Likert scale, from "strongly disagree" (1), "disagree" (2), "neither agree nor disagree" (3), "agree" (4), to "strongly agree" (5), with higher scores indicating greater severity of potential symptomatology [56], and therefore, a higher risk for EA. In this study, the EAI demonstrated acceptable internal reliability (Cronbach's $\alpha = 0.767$).

Physical activity measurement

A modified version of the International Physical Activity Questionnaire (IPAQ) was employed to assess the self-reported intensity and frequency of physical activity [57, 58]. Although our primary focus was on psychological addiction to exercise rather than physical activity levels per se, we examined correlations between the EAI and IPAQ to establish convergent validity. Results showed that EAI was correlated with exercise intensity ($r = 0.26$, $p < 0.01$) but not with total exercise days ($r = 0.028$, $p > 0.05$).

Muscularity-oriented eating testing

The Muscularity-Oriented Eating Test (MOET) was used to evaluate eating attitudes and behaviors associated with pursuing muscularity (e.g., *"I have been deliberately trying to limit the overall volume of some foods so that my muscles look more defined"* and *"What I ate has influenced how I think about myself as a person."*) [59]. This self-report questionnaire is a unidimensional measure consisting of 15 items, each rated on a 5-point Likert scale, from "never true" (1), "rarely true" (2), "sometimes true" (3), "often true" (4), to "always true" (5). In this

study, the sum score of MOET was used, with a higher score indicating a higher level of MOE symptoms [21]. Previous research has demonstrated good psychometric properties of the MOET [54], and in our study, the internal reliability of MOET was excellent (Cronbach's α = 0.935).

Resilience assessment

Resilience was assessed among participants by using the 7Cs resilience tool [56]. This self-report questionnaire comprises seven components of resilience (i.e., competence, confidence, connection, character, contribution, coping, and control) on a 3-point Likert scale from never (0), occasionally (1), to always (2), (60). The higher scores represent higher levels of resilience. In this study, the internal reliability of the 7Cs resilience tool was good (Cronbach's α = 0.822).

Covariates

We incorporated age, BMI derived from self-reported height and weight, and socioeconomic factors into our analysis as covariates. The socioeconomic factors included parental educational years and monthly financial status, rated on a 4-point Likert scale from very inadequate (1) to very adequate (4).

Statistical analysis

Descriptive statistics were summarized using IBM SPSS Statistics version 25.0 [61]. Pearson correlation analysis was conducted to display correlation coefficient matrices for variables and covariates. Missing data analysis revealed that less than 2% of data points were missing across all variables. We examined missing data patterns using Little's MCAR (Missing Completely At Random) test, which indicated that data were missing completely at random ($\chi^2 = 145.23$, $p = 0.156$). Given the pattern and minimal amount of missing data, we used full information maximum likelihood in the primary analyses, which yielded substantively identical results, confirming the robustness of our findings.

To test our hypotheses (Fig. 1), our path analyses comprised four stepwise models. Model 1 employed regression analysis to explore the associations of FI with EA and MOE. To examine the moderating effect of resilience on the associations mentioned earlier, we tested the interaction effect between FI and resilience on EA and MOE, where the term 'effect' referred to this statistical

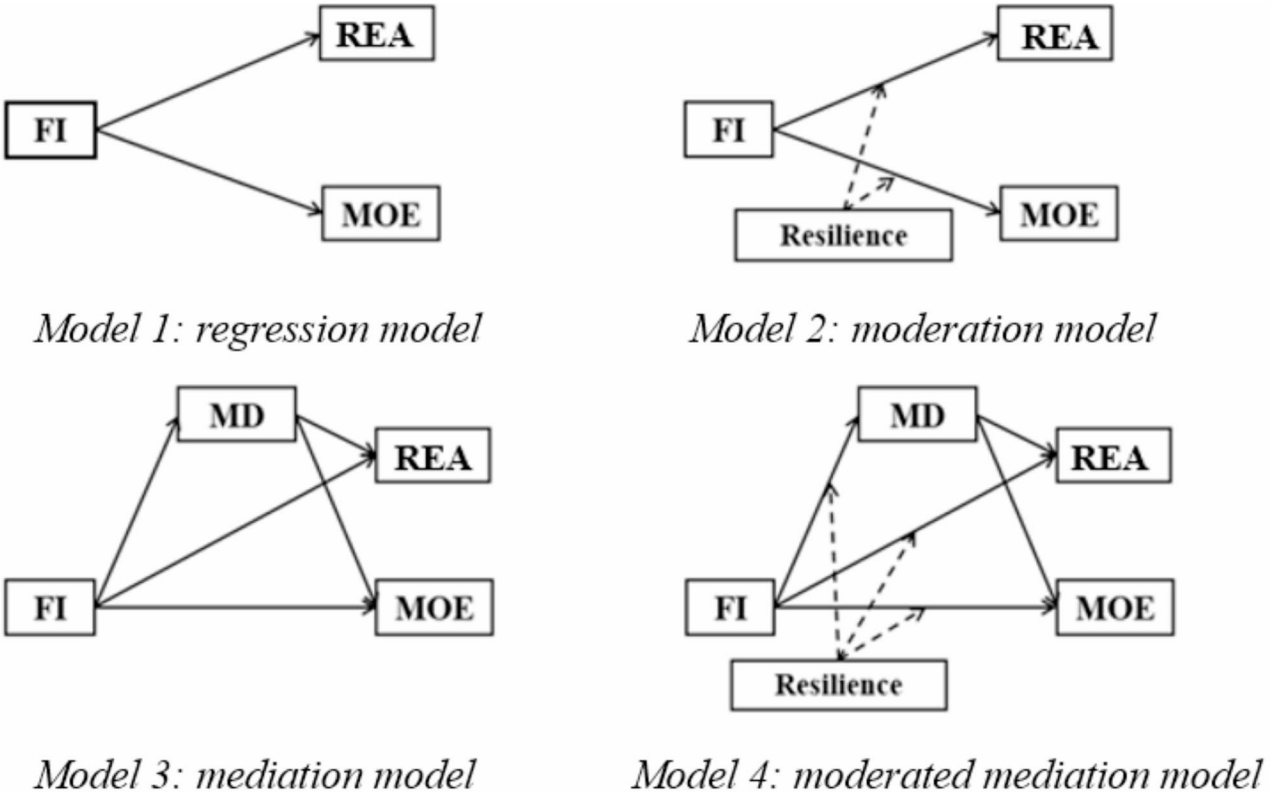

Fig. 1 The conceptual models of the main effect (Model 1), the moderating effect of resilience (Model 2), the mediating effect of muscle dysmorphia (Model 3), and the moderated mediating effect (Model 4) on exercise addiction and muscularity-oriented eating. The solid line represents the indirect and direct paths, and the dash line represents the moderating effect of resilience. FI indicates food insecurity; EA; exercise addiction; MOE, muscularity-oriented eating; MD, muscle dysmorphia

approach rather than causal inferences in Model 2. In Model 3, we assessed the mediating effect of MD on the paths from FI to EA and MOE. Lastly, we performed the moderated mediation analysis in Model 4, in which FI was an independent variable, EA and MOE were dependent variables, MD was the mediator, and resilience was the moderator of the mediating effect (Model 4). In this model, we classified the moderating effect of resilience on the mediating effect by dividing the interaction effect between FI and resilience on MD into three levels using centered mean and standard deviation (S.D.), low (centered mean − 1 S.D.), medium (centered mean), and high (centered mean + 1 S.D.). We additionally explored the gender difference in Model 4 by employing a multigroup model analysis (male vs. female groups) with a partial constraint technique to control for the variances of untargeted paths between the two groups. Each path in Model 4 (Fig. 2) was constrained to be equal one by one at a time to observe the effect of gender differences.

All model analyses, adjusted for covariates, were computed using a structural equation modeling analysis implemented in the Analyses of Moment Structures (AMOS) program version 24.0. In assessing the significance of our findings, the 95% confidence interval (CI), using bootstrapping methods with 5,000 repeated random samples, was utilized with all model analyses. Statistical significance was inferred if the 95% CI did not encompass zero [62]. For evaluating the tests, we adopted different indicators to represent the model fit, such as comparative fit index (CFI), Tucker-Lewis's index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR) [63]. An acceptable model fit has been proposed based on the criteria: CFI > 0.90. TLI > 0.90, RMSEA < 0.08, and SRMR < 0.08 [64].

Results

Descriptive statistics and bivariate correlation

The study analyzed data from a total of 1,500 participants (*Mage* = 22.20 [± 1.42] years), with 574 (38.3%) identified as male and 926 (61.7%) as female (Table 1). The average body mass index (BMI) was 21.76 (± 3.50) kg/m^2, and males had significantly higher BMI than females. Moreover, the average scores for MD, EA, and MOE were notably higher in males, while FI and resilience scores were not different between genders. Furthermore, most bivariate correlation coefficients among the key variables were significant, except for resilience and EA (Table 2). FI was positively correlated with MD, EA, and MOE, while resilience was negatively correlated with FI, MD, and MOE.

Effect of FI and its interaction effect with resilience on EA and MOE

Multiple fit indices showed acceptable model fits for our models (supplementary Table S1). In Model 1, the analysis revealed significant positive associations between FI and EA (β = 0.596, [95%CI: 0.245; 0.959]) and between

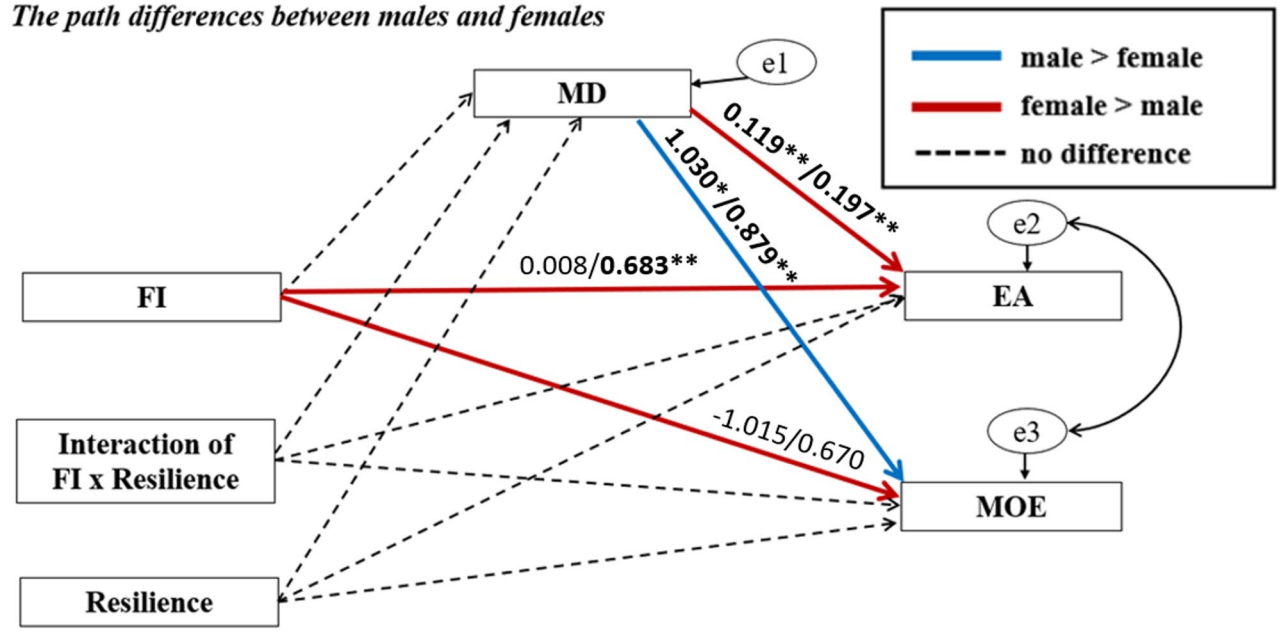

Fig. 2 The path differences between male and female groups. The significant difference of unstandardized regression weights between both genders are presented in solid lines. The blue solid line represents the stronger coefficients in male group. The red solid line represents the stronger coefficients in the female group. First and latter numbers on the paths are the coefficients in male and female groups respectively. FI indicates food insecurity; EA; exercise addiction; MOE, muscularity-oriented eating; MD, muscle dysmorphia. *$p < 0.05$; **$p < 0.01$

Table 1 Demographic characteristics and psychometric measure scores for all participants and stratified by gender

Key variables, mean (S.D.)	All (*n* = 1,500)	Male (*n* = 574)	Female (*n* = 926)	t (*p*-value)
Food insecurity[a]	1.51 (0.70)	1.53 (0.69)	1.49 (0.71)	1.045 (0.296)
Resilience[b]	17.22 (2.77)	17.24 (2.80)	17.21 (2.74)	0.150 (0.881)
Muscle dysmorphia[c]	27.24 (7.94)	30.11 (8.28)	25.46 (7.17)	**11.117 (< 0.001)**
Risk of exercise addiction[d]	16.04 (4.39)	17.46 (4.40)	15.16 (4.14)	**10.211 (< 0.001)**
Muscularity-oriented eating[e]	29.10 (12.15)	31.90 (14.58)	27.36 (9.98)	**6.575 (< 0.001)**
Covariate, mean (S.D.)				
Age (years)	22.20 (1.42)	22.30 (1.38)	22.13 (1.40)	**2.258 (0.024)**
Father's education (years)	14.50 (2.27))	14.57 (2.17)	14.46 (2.33)	0.913 (0.361)
Mother's education (years)	14.13 (2.15)	14.14 (2.11)	14.12 (2.18)	0.202 (0.840)
Monthly financial status	2.99 (0.72)	2.99 (0.71)	2.99 (0.73)	0.044 (0.965)
Body mass index (kg/m^2)	21.76 (3.50)	23.00 (3.45)	20.99 (3.31)	**11.254 (< 0.001)**

S.D.: Standard Deviation, n: number. Significant mean differences at the level 0.05 (2-tailed) are in bold format. [a] measured by a single-item food insecurity measure; [b] measured by a sum score of resilience questionnaire; [c] measured by a sum score of Muscle Dysmorphia Disorder Inventory; [d] measured by a sum score of Exercise Addiction Inventory; [e] measured by a sum score of Muscularity Oriented Eating Test

FI and MOE (β = 1.820, [0.937; 2.761]) (Table 3). Considering resilience in Model 2, the moderation analysis revealed a significant interaction effect between FI and resilience on MOE (β = 0.349, [0.052; 0.624]), but not on EA (β = 0.093, [-0.023; 0.215]).

Mediation role of MD and moderation role of resilience

In Model 3, the mediation analysis found that MD mediated the effects of FI on EA and MOE (Table 4). Specifically, the results showed significant indirect effects of FI via MD on EA (β = 0.431, [0.312, 0.56]) and MOE (β = 2.300, [1.707, 2.887]). The direct effects were not significant when MD was added to the model, thereby reinforcing the argument for the mediating role of MD in the relationships between FI and EA, and between FI and MOE. Further, we assessed the moderating role of resilience in both the direct and indirect effects of FI on EA and MOE in Model 4. For moderated direct effects, the interaction term between FI and resilience was not associated with either EA or MOE. On the other hand, the

Table 3 The effect of food insecurity and its interaction effect with resilience on the risk of exercise addiction and muscularity-oriented eating in all samples

Pathways	β	95% CI	*p*-value
Model 1			
FI -> EA	**0.596**	**0.245, 0.959**	**0.002**
FI -> MOE	**1.820**	**0.937, 2.761**	**< 0.001**
Model 2			
FI -> EA	**0.778**	**0.415, 1.156**	**< 0.001**
FI -> MOE	**1.951**	**0.928, 2.937**	**< 0.001**
Resilience -> EA	**0.107**	**0.012, 0.200**	**0.028**
Resilience -> MOE	-0.196	-0.411, 0.022	0.080
FI x resilience -> EA	0.093	-0.023, 0.215	0.116
FI x resilience -> MOE	**0.349**	**0.052, 0.624**	**0.025**

The beta estimates (β) are significant at the 0.05 level (2-tailed), and significant results are in bold format. FI indicates food insecurity; EA, exercise addiction; MOE, muscularity-oriented eating

Table 4 The effect of muscle dysmorphia (mediator) on the relationship between food insecurity, risk of exercise addiction, and muscularity-oriented eating in all samples

Pathways	β	95% CI	*p*-value
Model 3			
FI -> MD	**2.456**	**1.818, 3.042**	**< 0.001**
MD -> EA	**0.176**	**0.148, 0.205**	**< 0.001**
MD -> MOE	**0.937**	**0.864, 1.007**	**< 0.001**
FI -> MD -> EA	**0.431**	**0.312, 0.563**	**< 0.001**
FI -> MD -> MOE	**2.300**	**1.707, 2.887**	**< 0.001**
FI -> EA	0.227	-0.113, 0.575	0.201
FI -> MOE	-0.148	-0.828, 0.606	0.692

The beta estimates (β) are significant at the 0.05 level (2-tailed) and significant results are in bold format. FI indicates food insecurity; EA, exercise addiction; MOE, muscularity-oriented eating; MD, muscle dysmorphia

Table 2 Bivariate Pearson's correlations among psychometric measures and demographic covariates (*n* = 1,500)

		1	2	3	4	5	6	7	8	9
1	Food insecurity	--								
2	Resilience	**−0.327****	--							
3	Muscle dysmorphia	**0.217****	**−0.225****	--						
4	Exercise addiction	**0.108****	0.013	**0.340****	--					
5	Muscular-oriented eating	**0.090****	**−0.064***	**0.604****	**0.392****	--				
6	Age	0.020	0.036	**0.080****	**0.053***	0.041	--			
7	Father's education	**−0.158****	**0.083****	−0.015	0.021	**0.070****	**−0.081****	--		
8	Mother's education	**−0.157****	**0.055***	−0.003	0.045	**0.073****	−0.048	**0.675****	--	
9	Monthly financial status	**−0.410****	**0.314****	**−0.147****	**−0.073****	−0.020	0.003	**0.122****	**0.128****	--
10	Body mass index	**0.088****	**−0.087****	**0.137****	**0.128****	**0.103****	**0.114****	**−0.054***	**−0.063***	**−0.086****

**, * Correlation coefficients are significant at the level 0.01 and 0.05 (2-tailed), respectively. Significant correlation coefficients are in bold format

interaction between FI and resilience was significantly associated with MD (β = 0.359 [0.169; 0.551]), contributed to significant moderated indirect effects with indices of moderated mediation for EA (0.068, [0.033; 0.108]) and MOE (0.343, [0.163; 0.532]) (Table 5). Specifically, the indirect effect of FI on outcome variables via MD varied by levels of resilience, with a more substantial effect at a higher level of resilience.

Effect of gender on the association between FI, EA, and MOE

Gender differences were further investigated in the path analysis using a partial constraint technique (Fig. 2). We observed stronger associations of FI with outcome variables in females than in males. MD was more strongly associated with EA but less with MOE in females than in males. As such, results found a more substantial indirect effect of FI on MOE via MD in males than in females (Table 5). Furthermore, indirect effects differed by levels of resilience for both EA (index of moderated mediation = 0.068 [0.026; 0.118]) and MOE (index of moderated mediation = 0.301 [0.118, 0.507]) only in females (Table 5).

Discussion

Food insecurity and exercise addiction (H1a)

Using multiple models to dissect the complex relationship, results found that FI was associated with increased risks for EA, supporting our first hypothesis (H1a). This finding implies the potential adverse effects of FI on exercise behaviors. A prior study showed that more vigorous exercise patterns were found in food-insecure adults with mental illness than in food-secure counterparts [19], although the comparison test was not statistically significant. Their findings may still suggest more diverse physical activity types, as well as total and moderate weekly minutes, in highly food-insecure individuals. However, some studies have reported conflicting results, demonstrating lower physical activity levels among individuals with FI [17, 18] or no association between FI and physical activity [65]. Discrepant results may be due to the use of different measurement tools and methodologies. Most previous studies have focused on and quantified physical activity levels using IPAQ, whereas our study used the EAI to capture the risk of EA. As behavioral addiction usually encompasses psychological factors such as salience, intolerance, and mood modification, risk for EA is not determined solely by the amount of time spent exercising [66]. Likewise, results found a significant positive correlation between EA and subjective exercise intensity but not total exercise days based on the IPAQ. Therefore, the EAI captures the psychological and behavioral dimensions of exercise rather than merely

Table 5 The results of the moderated mediation analysis (model 4) in all samples and stratified by gender

Pathways	All			Male			Female			Male-Female		
	B	95% CI	*p*-value	B	95% CI	*p*-value	B	95% CI	*p*-value	B	95% CI	*p*-value
Conditional indirect effects on EA moderated by resilience levels												
Low (mean − 1 S.D)	**0.210**	**0.074**, **0.355**	**0.002**	**0.222**	**0.068**, **0.439**	**0.002**	0.148	-0.007, 0.320	0.063	0.074	-0.154, 0.331	0.541
Medium (mean)	**0.394**	**0.268**, **0.531**	**< 0.001**	**0.315**	**0.165**, **0.521**	**< 0.001**	**0.312**	**0.172**, **0.485**	**< 0.001**	0.003	-0.214, 0.246	0.966
High (mean + 1 S.D.)	**0.578**	**0.399**, **0.776**	**< 0.001**	**0.408**	**0.199**, **0.696**	**< 0.001**	**0.476**	**0.276**, **0.729**	**< 0.001**	-0.068	-0.368, 0.291	0.744
Conditional indirect effects on MOE moderated by resilience levels												
Low (mean − 1 S.D)	**1.078**	**0.366**, **1.760**	**0.003**	**1.921**	**0.598**, **3.383**	**0.004**	0.658	-0.045, 1.394	0.069	1.264	-0.192, 2.870	0.096
Medium (mean)	**2.022**	**1.413**, **2.656**	**< 0.001**	**2.726**	**1.618**, **3.857**	**< 0.001**	**1.388**	**0.770**, **2.060**	**< 0.001**	**1.338**	**0.122**, **2.684**	**0.031**
High (mean + 1 S.D.)	**2.965**	**2.079**, **3.892**	**< 0.001**	**3.530**	**1.946**, **5.326**	**< 0.001**	**2.119**	**1.234**, **3.094**	**< 0.001**	1.412	-0.407, 3.489	0.123
Indirect effect												
FI -> MD -> EA	**0.394**	**0.268**, **0.531**	**< 0.001**	**0.316**	**0.167**, **0.517**	**< 0.001**	**0.310**	**0.170**, **0.483**	**< 0.001**	0.006	-0.210, 0.251	0.930
FI -> MD -> MOE	**2.020**	**1.412**, **2.655**	**< 0.001**	**2.739**	**1.644**, **3.888**	**< 0.001**	**1.380**	**0.766**, **2.052**	**< 0.001**	**1.359**	**0.152**, **2.674**	**0.025**
Index of moderated mediation												
Index on EA	**0.066**	**0.032**, **0.105**	**0.001**	0.026	-0.018, 0.072	0.224	**0.068**	**0.026**, **0.118**	**0.001**	-0.042	-0.104, 0.019	0.185
Index on MOE	**0.341**	**0.163**, **0.528**	**0.001**	0.223	-0.165, 0.574	0.260	**0.301**	**0.118**, **0.507**	**0.001**	-0.077	-0.502, 0.328	0.724

FI: Food insecurity; MD: Muscle dysmorphia; Res: Resilience; EA: Exercise addiction; MOE: Muscularity-oriented eating; SS: Simple slope; CIE: Conditional indirect effect. The beta estimates are significant at the 0.05 level (2-tailed) and significant results are in bold format

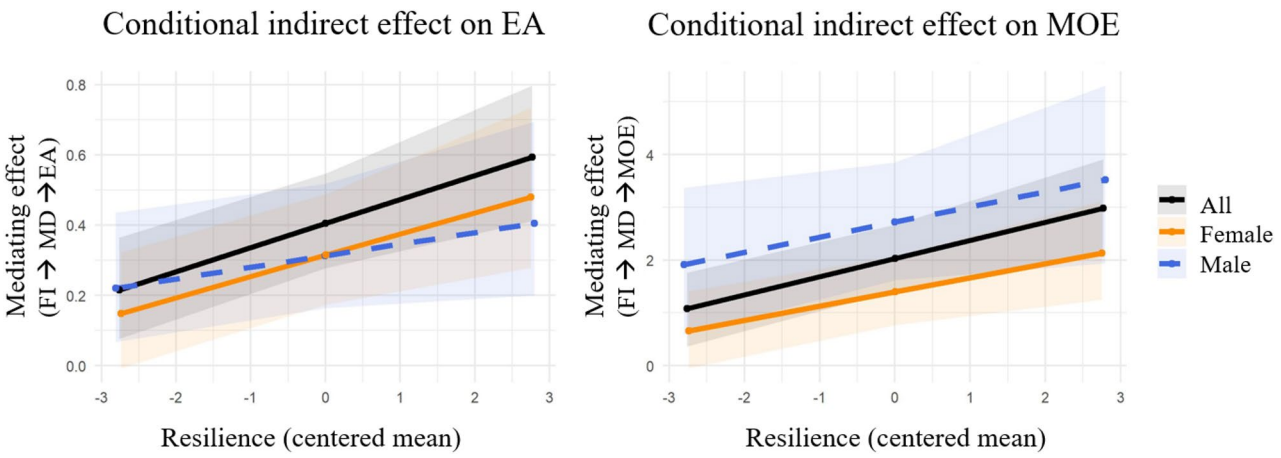

Fig. 3 The conditional indirect effects of food insecurity on exercise addiction (left) and muscularity-oriented eating (right) through muscle dysmorphia, at different resilience levels. X-axis represents the levels of resilience (centered means) and the y-axis represents the mediating effects. The slope of the plot represents the index of moderated mediation. The solid and dashed lines represent a significant and non-significant index of moderated mediation at $p < 0.05$ respectively

measuring exercise quantity, potentially explaining our differing findings.

Food insecurity and muscularity-oriented eating (H1b)

In addition to the relationship between FI and EA risks, results showed that FI was associated with MOE tendencies, further supporting hypothesis H1. Some systematic reviews have summarized a positive association between FI and eating disorders in adults [9]. as well as in children [67]. The main argument for this association is that food intake oscillates according to fluctuating food access. Therefore, food intake decreases during periods of food scarcity due to either voluntary or involuntary restriction and increases during periods of relative food abundance, when restrictions are no longer in place, among individuals living with FI [9]. While MOE may represent a unique array of eating disorder pathologies accompanied by the pursuit of muscular body image [20], its relationship with FI has not been considerably explored yet. A supporting study found that FI increased MD symptoms in Canadian populations [33]. Correspondingly, our study extended current knowledge to the link between FI and MOE tendencies. That said, those experiencing FI may save money by restricting regular meals in order to instead consume high loads of protein to gain muscularity.

The mediating role of muscle dysmorphia (H2)

The mediation analysis revealed that MD is crucial in the relationship between FI, EA, and MOE, supporting hypothesis H2. Several possibilities explain how FI influences EA and MOE through MD. Firstly, individuals with FI often have limited access to healthy food and experience fluctuating weight status during food availability-scarcity cycles, affecting body dissatisfaction due to the inability to maintain weight and body ideals [68]. Furthermore, FI can potentially influence body dissatisfaction through internalized weight stigma and self-discrimination, resulting in an unsatisfying image and requiring stronger desires to lose or gain weight, which may eventually link to developing MD in this cohort [69, 70]. Secondly, stress and anxiety during food scarcity can intensify body dissatisfaction and MD symptomatology [71, 72], especially in appearance intolerance [73]. Individuals with FI commonly exhibit low self-esteem, making them susceptible to socially comparing their body image and developing body image dissatisfaction and MD symptoms [74]. Thirdly, Bucchianeri et al. suggested that individuals with FI may isolate themselves due to financial challenges, become more conscious of their bodies, and develop body concerns and dissatisfaction [75]. Consequently, these people with FI-influenced MD potentially adopt maladaptive strategies, such as EA and MOE, to cope with their perception of lacking muscularity and leanness. Additionally, a previous study on MD and EA has reported increasing tendencies of EA and muscle dissatisfaction with rising MD symptoms, suggesting that individuals with EA and MD often exhibit similar attachment styles that can lead to negative decision-making processes and inappropriately selected strategies to achieve sufficient emotional regulation [76].

The moderating role of resilience (H3 and H4)

We tested resilience as a moderator of the indirect effects through MD and direct effects between FI and EA, as well as between FI and MOE, examining hypotheses H3 and H4. Results showed that resilience positively moderated the associations between FI and EA-MOE. When resilience increased, the influence of FI on MD was likely to increase, resulting in more substantial indirect effects (Fig. 3). The moderating effect of resilience on

indirect effects seemed counterintuitive, as resilience was expected to counteract the adverse impact of FI on EA and MOE. However, resilience alone significantly decreased the tendency for MD and attenuated the association between the interaction of FI-resilience and MD compared to the association between FI and MD alone. Although resilience may not entirely eliminate the adverse impact of FI on MD, it implies a positive effect on the associations between FI, EA, and MOE.

Gender differences (H5)

Finally, we assessed the effect of gender differences in the moderated mediation model, testing hypothesis H5. The results illustrated that FI solely increased EA and MOE via MD in both genders, while resilience only moderated this indirect effect in females. These findings suggested a more substantial indirect effect when resilience increased in females only. In contrast, this indirect effect was significant regardless of resilience levels in males. In addition, the results of the path analysis presented a stronger association between MD and MOE in males, as the association between MD and EA was more robust in females, illustrating that females tended to adopt exercises and were more likely to develop EA behaviors. However, males tended to select MOE as their coping strategy. Interestingly, our findings were aligned with previous studies, which reported that females primarily focused on being thin and lean, while males focused on being thick, large, and muscular [77, 78]. With our results, females may choose exercise to lose fat and maintain their body image. In contrast, males may adopt supplementary diets, such as whey protein, and utilize bulking and cutting strategies to achieve greater muscularity.

Clinical and public health implications

The present findings point to several issues that may be relevant for clinical practice and public health. First, for healthcare providers working with food-insecure young adults, it may be helpful to consider the possible co-occurrence of muscle dysmorphia, exercise addiction, and muscularity-oriented eating behaviors, as these patterns warrant further examination in future clinical research. Second, although addressing food insecurity fundamentally requires structural solutions that improve food availability and access, our results suggest that psychosocial factors such as resilience may play a complementary role in shaping vulnerability to body image-related concerns among food-insecure individuals. Third, the observed gender differences indicate that future prevention or support efforts could benefit from attending to sex-specific patterns, including muscularity-related sociocultural pressures among males and exercise-related concerns among females. Finally, future research may explore whether targeted resilience-building strategies (e.g., coping skills training, stress-management interventions, or programs that enhance social support) could help mitigate the psychological burden associated with food insecurity in young adulthood.

Limitations

Although this study provides insightful connections between FI, body image concerns, and EA and MOE, it has several limitations. Firstly, the observational, cross-sectional design limits causal inferences within a specific period. The SEM analysis only examined one potential direction of association effects, where reverse causality might exist. Also, other potential mediating variables, such as anxiety and depression, may also mediate these relationships. Secondly, the data were self-reported, which may introduce bias. The questionnaires were not intended for diagnostic purposes; thus, these scores represented tendencies or risks of behavioral addictions or disorders. Thirdly, a single-item question of food insecurity is practical for extensive surveys and previously validated, but does not fully capture the complexity and multidimensional nature of food insecurity experiences. This question assesses worry about food affordability, rather than actual experiences of food scarcity, hunger, or compromised diet quality, and does not distinguish between chronic food insecurity and transient concerns. Future studies should employ more comprehensive, validated multi-item food insecurity measures (e.g., the 10-item United States Department of Agriculture Food Security Scale Module) [79] to better characterize the severity, duration, and specific dimensions of food insecurity, as well as their differential relationships with body image and eating behaviors. Longitudinal studies are also needed to elucidate the temporal sequence and causal relationships among FI, EA, and MOE.

Conclusion

This study suggests that FI may be associated with increased tendencies of EA and MOE through a crucial mechanism of body image concerns. In this relationship, resilience may play a moderation role, and hence, it can be leveraged to attenuate the indirect effect via MD among individuals living in a food-insecure environment. Our findings may shed light on future empirical research promoting resilience in this vulnerable population when tackling their exercise and eating behaviors.

Supplementary Information

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Supplementary Material 1.

Author contributions
Study concept and design: SC, MCT, CYL, CS, KR, CXT, AKN, CTL.Data collection and coordination: SC, MCT, KR.Analysis and interpretation of data: All authors. Statistical analysis: SC, MCT, CYL, CS, CXT, AK, BSB, PYL, YHS.Manuscript drafting: SC, MCT.Critical revision and intellectual content: All authors. Obtained funding: SC, MCT.Study supervision: SC, MCT, CTL.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study procedures were carried out in accordance with the 2013 Declaration of Helsinki and approved by the Institutional Review Board of the National Cheng Kung University Hospital (A-ER-110-571). All participants gave informed consent and waived the need for a written form by returning anonymous questionnaires.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Pediatrics, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan
[2]Institute of International Medical Device Innovation, College of Engineering, National Cheng Kung University, Tainan, Taiwan
[3]Department of Family Medicine, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, 138 Sheng-Li Road, Tainan 704, Taiwan
[4]Institute of Allied Health Sciences, College of Medicine, National Cheng Kung University, Tainan, Taiwan
[5]School of Nursing, College of Nursing, Kaohsiung Medical University, Kaohsiung, Taiwan
[6]Department of Public Health, College of Medicine, National Cheng Kung University, Tainan, Taiwan
[7]Department of Biological Sciences, School of Medicine and Life Sciences, Sunway University, Subang Jaya, Selangor, Malaysia
[8]Department of Social and Preventive Medicine, Faculty of Medicine, Universiti Malaya, Kuala Lumpur, Malaysia
[9]Department of Allied Health Sciences, Faculty of Science, Universiti Tunku Abdul Rahman, Kampar, Perak, Malaysia
[10]Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, Serdang, Selangor, Malaysia
[11]Department of Health Behaviour, Environment, and Social Medicine, Faculty of Medicine Public Health and Nursing, Gadjah Mada University, Yogyakarta, Indonesia
[12]Psychophysiology Laboratory, Department of Humanities and Social Sciences, Indian Institute of Technology Bombay, Mumbai, India
[13]Department of Medical Humanities and Social Medicine, College of Medicine, National Cheng Kung University, 1 University Road, Tainan 701, Taiwan
[14]Department of Genomic Medicine, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan

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References

1. Food insecurity. a neglected public health issue requiring multisectoral action. BMC Med. 2023;21(1):130.
2. Nations U. Goal 2: Zero hunger–United Nations sustainable development. 2015.
3. Yeh CW, Lo YC, Chen YC, Chen WC, Huang YC. Perceived Food Insecurity, Dietary Quality, and Unfavorable Food Intake among Children and Adolescents from Economically Disadvantaged Households. Nutrients. 2021;13(10).
4. Wu CH, Lin CY, Hsieh YP, Strong C, Meshki C, Lin YC, et al. Dietary behaviors mediate the association between food insecurity and obesity among socioeconomically disadvantaged youth. Appetite. 2019;132:275–81.
5. Levi R, Bleich SN, Seligman HK. Food Insecurity and Diabetes: Overview of Intersections and Potential Dual Solutions. Diabetes Care. 2023;46(9):1599–608.
6. Wolfson JA, Garcia T, Leung CW. Food Insecurity Is Associated with Depression, Anxiety, and Stress: Evidence from the Early Days of the COVID-19 Pandemic in the United States. Health Equity. 2021;5(1):64–71.
7. Royer MF, Guerithault N, Braden BB, Laska MN, Bruening M. Food insecurity is associated with cognitive function: a systematic review of findings across the life course. Int J Transl Med. 2021;1(3):205–22.
8. Lee CT, Pramukti I, Ubeda Herrera JJ, Tsai MC. Investigating psychological distress and peer influence in the longitudinal path linking food insecurity to adolescent substance use: a nationwide low-income cohort study. Psychol Health Med. 2024;29(3):556–73.
9. Hazzard VM, Loth KA, Hooper L, Becker CB. Food Insecurity and Eating Disorders: a Review of Emerging Evidence. Curr Psychiatry Rep. 2020;22(12):74.
10. Tsai MC, Gan ST, Lee CT, Liang YL, Lee LT, Lin SH. National population-based data on the incidence, prevalence, and psychiatric comorbidity of eating disorders in Taiwanese adolescents and young adults. Int J Eat Disord. 2018;51(11):1277–84.
11. Chen DR, Lin LY, Levin B. Differential pathways to disordered eating for immigrant and native adolescents in Taiwan. J Eat Disord. 2023;11(1):54.
12. Kosmas JA, Garza M, Kells M, Hahn SL, Davis HA. Food insecurity predicts excessive exercise, dietary restriction, cognitive restraint, and purging, but not binge eating, in college students across 3 months. Int J Eat Disord. 2025;58(5):952–63.
13. Szabo A, Demetrovics Z. Passion and addiction in sports and exercise. Routledge; 2022.
14. Association AP. Diagnostic and statistical manual of mental disorders (5th ed., text rev.). 2022.
15. Leung CW, Parnarouskis L, Slotnick MJ, Gearhardt AN. Food Insecurity and Food Addiction in a Large, National Sample of Lower-Income Adults. Curr Dev Nutr. 2023;7(12):102036.
16. Turner VE, Demissie Z, Sliwa SA, Clayton HB. Food Insecurity and Its Association With Alcohol and Other Substance Use Among High School Students in the United States. J Sch Health. 2022;92(2):177–84.
17. Maia I, Oliveira A, Santos AC. Food insecurity is associated with an unhealthy lifestyle score in middle- and older-aged adults: findings from the EPIPorto cohort. Food Secur. 2023;15(3):661–71.
18. To QG, Frongillo EA, Gallegos D, Moore JB. Household food insecurity is associated with less physical activity among children and adults in the U.S. population. J Nutr. 2014;144(11):1797–802.
19. Taylor Cunningham A, Carson Weinstein L, Stefancic A, Silverio A, Cabassa LJ. The association between food insecurity and physical activity in adults with serious mental illness living in supportive housing. Prev Med Rep. 2022;30:102008.
20. Messer M, Duxson S, Diluvio P, McClure Z, Linardon J. The independent contribution of muscularity-oriented disordered eating to functional impairment and emotional distress in adult men and women. Eat Disord. 2023;31(2):161–72.
21. Lavender JM, Brown TA, Murray SB. Men, muscles, and eating disorders: an overview of traditional and muscularity-oriented disordered eating. Curr Psychiatry Rep. 2017;19(6):32.
22. Murray SB, Griffiths S, Mond JM. Evolving eating disorder psychopathology: conceptualising muscularity-oriented disordered eating. Br J Psychiatry. 2016;208(5):414–5.
23. Eisenberg ME, Wall M, Neumark-Sztainer D. Muscle-enhancing behaviors among adolescent girls and boys. Pediatrics. 2012;130(6):1019–26.
24. Nagata JM, McGuire FH, Lavender JM, Brown TA, Murray SB, Compte EJ, et al. Appearance and performance-enhancing drugs and supplements (APEDS): Lifetime use and associations with eating disorder and muscle dysmorphia symptoms among cisgender sexual minority people. Eat Behav. 2022;44:101595.

25. Abene JA, Tong J, Minuk J, Lindenfeldar G, Chen Y, Chao AM. Food insecurity and binge eating: A systematic review and meta-analysis. Int J Eat Disord. 2023;56(7):1301–22.
26. Lydecker JA, Grilo CM. Food insecurity and bulimia nervosa in the United States. Int J Eat Disord. 2019;52(6):735–9.
27. Jackson DB, Newsome J, Vaughn MG, Johnson KR. Considering the role of food insecurity in low self-control and early delinquency. J Crim Justice. 2018;56:127–39.
28. Morales ME, Berkowitz SA. The Relationship between Food Insecurity, Dietary Patterns, and Obesity. Curr Nutr Rep. 2016;5(1):54–60.
29. Kim SM, Park YJ, Kim H, Kwon O, Ko KS, Kim Y et al. Associations of Food Insecurity with Dietary Inflammatory Potential and Risk of Low Muscle Strength. Nutrients. 2023;15(5).
30. Murray SB, Touyz SW. Muscle dysmorphia: towards a diagnostic consensus. Aust N Z J Psychiatry. 2013;47(3):206–7.
31. Chung B. Muscle dysmorphia: a critical review of the proposed criteria. Perspect Biol Med. 2001;44(4):565–74.
32. Foster AC, Shorter GW, Griffiths MD. Muscle dysmorphia: could it be classified as an addiction to body image? J Behav Addict. 2015;4(1):1–5.
33. Ganson KT, Pang N, Rodgers RF, Testa A, Murray SB, Nagata JM. Masculinity and muscle dysmorphia in mixed gender Canadian youth. Sex Roles. 2024;90(5):628–41.
34. Pace U, D'Urso G, Passanisi A, Mangialavori S, Cacioppo M, Zappulla C. Muscle dysmorphia in adolescence: The role of parental psychological control on a potential behavioral addiction. J Child Fam Stud. 2020;29:455–61.
35. Gebre GG, Isoda H, Amekawa Y, Rahut DB, Nomura H, Watanabe T. What explains gender gaps in household food security? Evidence from maize farm households in southern Ethiopia. Soc Indic Res. 2021;155(1):281–314.
36. Silva A, Astorga A, Faundez R, Santos K. Revisiting food insecurity gender disparity. PLoS ONE. 2023;18(8):e0287593.
37. Jung NM, de Bairros FS, Pattussi MP, Pauli S, Neutzling MB. Gender differences in the prevalence of household food insecurity: a systematic review and meta-analysis. Public Health Nutr. 2017;20(5):902–16.
38. Koller EC, Egede LE, Garacci E, Williams JS. Gender Differences in the Relationship Between Food Insecurity and Body Mass Index Among Adults in the USA. J Gen Intern Med. 2022;37(16):4202–8.
39. Dinour LM, Bergen D, Yeh MC. The food insecurity-obesity paradox: a review of the literature and the role food stamps may play. J Am Diet Assoc. 2007;107(11):1952–61.
40. Tayie FA, Zizza CA. Food insecurity and dyslipidemia among adults in the United States. Prev Med. 2009;48(5):480–5.
41. Royer MF, Rosas LG, King AC. Food insecurity and cardiovascular disease risk factors among U.S. adults. BMC Public Health. 2025;25(1):817.
42. Dumitru D, Dumitru Dumitru T, Maher A. A systematic review of exercise addiction: Examining gender differences. J Phys Educ Sport. 2018;18(3):1738.
43. Nagata JM, Murray SB, Bibbins-Domingo K, Garber AK, Mitchison D, Griffiths S. Predictors of muscularity-oriented disordered eating behaviors in U.S. young adults: A prospective cohort study. Int J Eat Disord. 2019;52(12):1380–8.
44. Malcolm A, Pikoos TD, Castle DJ, Rossell SL. An update on gender differences in major symptom phenomenology among adults with body dysmorphic disorder. Psychiatry Res. 2021;295:113619.
45. Wang Y-C, Guerola MM, Lin Y-C, Hsieh Y-P, Strong C, Tsai M-C, et al. Effects of childhood adversity and resilience on Taiwanese youth health behaviors. Pediatr Neonatol. 2019;60(4):368–76.
46. Thurston IB, Hardin R, Kamody RC, Herbozo S, Kaufman C. The moderating role of resilience on the relationship between perceived stress and binge eating symptoms among young adult women. Eat Behav. 2018;29:114–9.
47. Luceño-Moreno L, Talavera-Velasco B, García-Albuerne Y, Martín-García J. Symptoms of Posttraumatic Stress, Anxiety, Depression, Levels of Resilience and Burnout in Spanish Health Personnel during the COVID-19 Pandemic. Int J Environ Res Public Health. 2020;17(15).
48. Alim TN, Lawson WB, Feder A, Iacoviello BM, Saxena S, Bailey CR, et al. Resilience to meet the challenge of addiction: psychobiology and clinical considerations. Alcohol Res. 2012;34(4):506–15.
49. Aboody D, Siev J, Doron G. Building resilience to body image triggers using brief cognitive training on a mobile application: A randomized controlled trial. Behav Res Ther. 2020;134:103723.
50. Nagata JM, Chu J, Cervantez L, Ganson KT, Testa A, Jackson DB, et al. Food insecurity and binge-eating disorder in early adolescence. Int J Eat Disord. 2023;56(6):1233–9.
51. Nagata JM, Compte EJ, McGuire FH, Lavender JM, Murray SB, Brown TA, et al. Psychometric validation of the Muscle Dysmorphic Disorder Inventory (MDDI) among U.S. transgender men. Body Image. 2022;42:43–9.
52. Hildebrandt T, Langenbucher J, Schlundt DG. Muscularity concerns among men: Development of attitudinal and perceptual measures. Body image. 2004;1(2):169–81.
53. Compte EJ, Nagata JM, Sepúlveda AR, Rivas A, Sbdar LS, Menga S, et al. Assessment and validation of a Spanish version of the Muscle Dysmorphia Disorder Inventory in Argentinian men who exercise: Inventario de Dismorfia Muscular. Body Image. 2019;31:24–34.
54. He J, Murray S, Compte EJ, Song J, Nagata JM. The Muscularity-Oriented Eating Test, Drive for Muscularity Scale, and Muscle Dysmorphic Disorder Inventory among Chinese Men: Confirmatory Factor Analyses. Int J Environ Res Public Health. 2021;18:21.
55. Griffiths MD, Szabo A, Terry A. The exercise addiction inventory: a quick and easy screening tool for health practitioners. Br J Sports Med. 2005;39(6):e30–e.
56. Terry A, Szabo A, Griffiths M. The exercise addiction inventory: A new brief screening tool. Addict Res Theory. 2004;12(5):489–99.
57. Lee CT, Lin CY, Strong C, Lin YF, Chou YY, Tsai MC. Metabolic correlates of health-related quality of life among overweight and obese adolescents. BMC Pediatr. 2018;18(1):25.
58. Liou YM, Jwo CJC, Yao KG, Chiang L-C, Huang L-H. Selection of appropriate Chinese terms to represent intensity and types of physical activity terms for use in the Taiwan version of IPAQ. J Nurs Res. 2008;16(4).
59. Murray SB, Brown TA, Blashill AJ, Compte EJ, Lavender JM, Mitchison D, et al. The development and validation of the muscularity-oriented eating test: A novel measure of muscularity-oriented disordered eating. Int J Eat Disord. 2019;52(12):1389–98.
60. Barger J, Vitale P, Gaughan JP, Feldman-Winter L. Measuring resilience in the adolescent population: A succinct tool for outpatient adolescent health. J Pediatr. 2017;189:201–6. e3.
61. Corp I. IBM SPSS Statistics for Windows 25 ed. Armonk, NY: IBM Corp; 2017.
62. Lin C-Y, Tsai M-C. Effects of family context on adolescents' psychological problems: Moderated by pubertal timing, and mediated by self-esteem and interpersonal relationships. Appl Res Qual Life. 2016;11:907–23.
63. Lt H, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct Equ Model. 1999;6(1):1–55.
64. Tsai MC, Strong C, Lin CY. Effects of pubertal timing on deviant behaviors in Taiwan: A longitudinal analysis of 7th- to 12th-grade adolescents. J Adolesc. 2015;42:87–97.
65. Chakraborty R, Armijos RX, Weigel MM. Household food insecurity and physical activity behaviour in Ecuadorian children and adolescents: findings from the Ecuador 2018 National Health and Nutrition Survey (ENSANUT-2018). Public Health Nutr. 2024;27(1):e67.
66. Kovacsik R, Griffiths MD, Pontes HM, Soós I, de la Vega R, Ruíz-Barquín R, et al. The role of passion in exercise addiction, exercise volume, and exercise intensity in long-term exercisers. Int J Ment Health. 2019;17:1389–400.
67. Bidopia T, Carbo AV, Ross RA, Burke NL. Food insecurity and disordered eating behaviors in children and adolescents: A systematic review. Eat Behav. 2023;49:101731.
68. Altman EA, Ritchie LD, Frongillo EA, Madsen KA. Food Insecurity Is Associated with Body Dissatisfaction among Children in California. J Acad Nutr Diet. 2019;119(10):1732–7.
69. Becker CB, Middlemas K, Gomez F, Kilpela LS. An exploratory examination of internalized weight stigma in a sample living with food insecurity. Body Image. 2021;37:238–45.
70. Jung F, Spahlholz J, Hilbert A, Riedel-Heller SG, Luck-Sikorski C. Impact of weight-related discrimination, body dissatisfaction and self-stigma on the desire to weigh less. Obes Facts. 2017;10(2):139–51.
71. Murray K, Rieger E, Byrne D. The relationship between stress and body satisfaction in female and male adolescents. Stress Health. 2015;31(1):13–23.
72. Vannucci A, Ohannessian CM. Body Image Dissatisfaction and Anxiety Trajectories During Adolescence. J Clin Child Adolesc Psychol. 2018;47(5):785–95.
73. Ganson KT, Pang N, Testa A, Jackson DB, Nagata JM. Food insecurity is associated with muscle dysmorphia symptomatology among a sample of Canadian adolescents and young adults. Body Image. 2023;47:101628.
74. Ejiohuo O, Onyeaka H, Unegbu KC, Chikezie OG, Odeyemi OA, Lawal A, et al. Nourishing the mind: how food security influences mental wellbeing. Nutrients. 2024;16(4):501.

75. Bucchianeri MM, Arikian AJ, Hannan PJ, Eisenberg ME, Neumark-Sztainer D. Body dissatisfaction from adolescence to young adulthood: Findings from a 10-year longitudinal study. Body Image. 2013;10(1):1–7.
76. Olave L, Estévez A, Momeñe J, Muñoz-Navarro R, Gómez-Romero MJ, Boticario MJ, et al. Exercise Addiction and Muscle Dysmorphia: The Role of Emotional Dependence and Attachment. Front Psychol. 2021;12:681808.
77. Rodgers RF, Ganchou C, Franko DL, Chabrol H. Drive for muscularity and disordered eating among French adolescent boys: A sociocultural model. Body Image. 2012;9(3):318–23.
78. Tod D, Edwards C. A meta-analysis of the drive for muscularity's relationships with exercise behaviour, disordered eating, supplement consumption, and exercise dependence. Int Rev Sport Exerc Psychol. 2015;8(1):185–203.
79. Fiagbor R, Brown O. Assessing the 10-item food security survey model (FSSM): insights from college students in three US universities. Nutrients. 2025;17(6):1050.

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