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Fat mass and negative affect in healthy young adults: a cross-sectional pilot with exploratory sex-moderation analyses

Eric Schmalzried
Chatham University
Michael Collyer
Chatham University
Edward Ryan
Chatham University
Jason Edsall
Chatham University
Michael Nizinski
Chatham University
Sydney Weaver
Chatham University
Rebecca Pennington
Chatham University
John Dube
jdube@chatham.edu
Chatham University

Short Report

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Abstract

Objective

Adiposity has been associated with poorer psychological well-being, but data in healthy young adults remain limited. This cross-sectional study reports associations among adiposity, positive and negative affect, estimated cardiorespiratory fitness, and resting heart rate variability (HRV) in healthy young adults. We also conducted exploratory tests of whether adiposity–affect associations differed by sex.

Results

Fifty-five healthy young adults completed body composition, the Positive and Negative Affect Schedule, estimated cardiorespiratory fitness testing, and resting HRV. In fully adjusted hierarchical regression models, greater fat mass was associated with higher negative affect (B = 0.27, SE = 0.11, p = 0.02), while the inverse association with positive affect did not reach statistical significance (B = − 0.22, SE = 0.12, p = 0.08). Sex-by-fat mass interactions were not detected for positive affect (B = 0.20, SE = 0.20, p = 0.33) or negative affect (B = − 0.25, SE = 0.19, p = 0.20). lnRMSSD did not independently predict affect. A secondary sex-by-BMI-category interaction was observed for positive affect ($F[1,51] = 4.15$, $p = 0.047$, $\omega^2 = 0.053$), but not negative affect. These findings identify the fat mass–negative affect association as the most consistent pilot observation, while sex-moderation results should be considered preliminary.

Introduction

Excess adiposity has been linked to poorer psychological well-being, including higher depressive symptoms, distress, and affective burden (1–3). These associations are relevant in young adulthood, when changes in body composition and mental health commonly emerge but may remain subclinical. However, the relationship between adiposity and affect in otherwise healthy young adults remains incompletely characterized, particularly when affect is assessed dimensionally rather than as a clinical psychiatric endpoint (4).

Positive affect and negative affect are related but distinct dimensions of psychological functioning. Lower positive affect does not necessarily imply higher negative affect, and each may have different physiological or behavioral correlates (5). Examining both dimensions may therefore provide a more nuanced view of adiposity-related psychological variation in nonclinical samples.

Sex may also influence adiposity–affect associations because females and males differ in body composition, adipose tissue distribution, endocrine signaling, inflammatory biology, and autonomic regulation (6). However, small pilot studies are often not adequately powered to detect sex-by-adiposity interaction effects. In this context, direct tests of sex moderation can be useful for hypothesis generation, provided that null interaction findings are not interpreted as evidence of equivalence.

This study reports pilot data from a small cross-sectional study of healthy young adults designed to estimate associations between adiposity and affect and to generate preliminary evidence regarding whether these associations may differ by sex. We also examined whether estimated cardiorespiratory fitness and resting heart rate variability contributed additional explanatory value.

Main text

Study design and participants

This cross-sectional pilot study included healthy young adults recruited from a small liberal arts university in Pittsburgh, Pennsylvania. An initial recruitment email was distributed to enrolled undergraduate and graduate students. Interested students completed telephone screening to determine eligibility and confirm safety for laboratory testing.

Eligible participants were 18–35 years of age, able to safely walk on a treadmill, and free of diagnosed mental health disorders and cardiovascular, pulmonary, metabolic, or renal disease. Participants reported their sex as female or male; gender identity was not assessed. The research protocol was approved by the Chatham University Institutional Review Board (#IRB-FY2019-51), and all participants provided written informed consent before participation.

Participants were instructed to abstain from alcohol, caffeine, tobacco, and structured exercise for 24 hours before testing while otherwise maintaining their usual diet. Laboratory visits occurred in the morning and lasted approximately 90 minutes. Participants completed written informed consent, exercise-readiness screening, affect assessment, resting heart rate variability assessment, body composition testing, and treadmill-based estimated cardiorespiratory fitness testing.

Measures

Psychological affect was assessed using the Positive and Negative Affect Schedule. Participants completed the instrument after sitting quietly for 5 minutes and were instructed to respond using a 2-week reference period (7). Positive affect and negative affect were analyzed as separate affective dimensions.

Resting heart rate variability was assessed before exercise testing using a 12-lead electrocardiogram under standardized resting conditions. Participants rested supine in a quiet, temperature-controlled environment before a 5-minute electrocardiographic recording. R peaks were detected using manufacturer software, and recordings were visually reviewed for signal quality. Heart rate variability was quantified as the root mean square of successive differences between adjacent normal-to-normal R-R intervals. RMSSD values were natural log-transformed before analysis (8).

Height and body mass were measured using a stadiometer and beam scale and used to calculate body mass index. Percent body fat was estimated using handheld bioelectrical impedance analysis. Fat mass was calculated as body mass multiplied by body fat fraction, and fat-free mass was calculated by subtracting fat mass from total body mass.

Estimated cardiorespiratory fitness was assessed using a sex-specific Balke-Ware treadmill protocol. Exercise intensity was monitored using heart rate and rating of perceived exertion. Participants continued until volitional fatigue and then completed an active cool-down. Estimated maximal oxygen uptake was calculated using protocol-specific equations (9).

Statistical analysis

Analyses were planned to estimate associations between adiposity and affect and to explore whether these associations differed by sex. Descriptive data are presented as mean ± SEM. Raw RMSSD values are reported descriptively, whereas RMSSD was natural log-transformed before inferential analyses. Data distributions were assessed using Shapiro-Wilk tests, visual inspection of histograms and Q-Q plots, and evaluation of skewness and kurtosis. Homogeneity of variance was evaluated with Levene's test for group comparisons. Regression diagnostics included inspection of standardized residuals and influence statistics.

Body mass index category was treated as a secondary categorical operationalization of adiposity. Participants were classified as BMI < 25 kg/m² or BMI ≥ 25 kg/m². Two-way analysis of variance was used to test sex-by-BMI-category effects on positive affect and negative affect. Because BMI categorization can obscure graded associations, continuous adiposity models were treated as the primary analyses.

Primary inferential analyses used hierarchical linear regression models with positive affect and negative affect as dependent variables. Fat mass was specified a priori as the primary continuous adiposity index because it provides an interpretable estimate of absolute adiposity. Percent body fat was examined in sensitivity analyses because it expresses adiposity relative to body size. In each primary model, Model 1 included sex, age, estimated maximal oxygen uptake, and adiposity; Model 2 added the sex-by-adiposity interaction term; and Model 3 added lnRMSSD. Continuous predictors were mean-centered before

interaction terms were created. Regression results are reported as unstandardized coefficients, standard errors, model fit statistics, and change in explained variance.

Because this was a pilot study, sex-by-adiposity interaction terms were interpreted as exploratory tests of moderation. Non-significant interaction terms were not interpreted as evidence that associations were equivalent across females and males. Given the pilot, hypothesis-generating design and the limited sample size, p-values were interpreted descriptively, and no formal correction for multiple testing was applied.

Results

Participant characteristics are shown in Table 1. Fifty-five participants were included in the analyses, including 19 males and 36 females. Twenty-eight participants had BMI < 25 kg/m² and 27 had BMI ≥ 25 kg/m². Age did not differ by sex or BMI category. As expected, participants with BMI ≥ 25 kg/m² had higher BMI, body mass, percent body fat, and fat mass than participants with BMI < 25 kg/m². Males were taller and heavier than females and had lower percent body fat and higher lean mass. Resting heart rate and raw RMSSD did not differ by sex or BMI category. Estimated VO_2max was higher in males than females and tended to be lower in participants with BMI ≥ 25 kg/m² than in participants with BMI < 25 kg/m². No sex-by-BMI-category interactions were observed for participant characteristics.

Table 1
Subject characteristics.

	BMI < 25 kg/m^2						**BMI ≥ 25 kg/m^2**						**Male vs Female**	**BMI < 25 vs BMI ≥ 25**
	Male			**Female**			**Male**			**Female**			**p-value** ω^2 **[95% CI]**	**p-value** ω^2 **[95% CI]**
n	9			19			10			18				
Age (years)	22.6	±	0.8	23.1	±	0.7	24.9	±	1.5	23.3	±	1.0	p = 0.59 0.00 [0.00, 0.00]	p = 0.23 0.00 [0.00, 0.12]
Height (cm)	180.7	±	3.4	163.7	±	1.3	179.6	±	2.4	164.7	±	1.6	**p < 0.001** **0.52 [0.33, 0.66]**	p = 0.98 0.01 [0.00, 0.00]
Weight (kg)	71.0	±	2.3	59.2	±	1.7	92.4	±	2.8	78.1	±	3.0	**p < 0.001** **0.17 [0.03, 0.35]**	**p < 0.001** **0.42 [0.22, 0.57]**
BMI (kg/m^2)	22.5	±	0.6	22.0	±	0.5	29.0	±	1.0	28.7	±	0.9	p = 0.62 0.00 [0.00, 0.00]	**p < 0.001** **0.54 [0.36, 0.67]**
Body fat (%)	9.2	±	1.2	21.7	±	1.1	20.4	±	1.6	30.4	±	1.2	**p < 0.001** **0.39 [0.19, 0.55]**	**p < 0.001** **0.31 [0.12, 0.48]**
Lean mass (kg)	64.4	±	1.8	46.1	±	1.1	73.2	±	1.8	54.0	±	1.4	**p < 0.001** **0.64 [0.48, 0.75]**	**p < 0.001** **0.12 [0.00, 0.30]**
Fat mass (kg)	6.6	±	0.9	13.0	±	0.8	19.2	±	2.0	24.2	±	1.8	**p < 0.001**	**p < 0.001**

Data are mean ± SEM. Participants were categorized as BMI < 25 kg/m² or BMI ≥ 25 kg/m² for secondary categorical analyses. Main effects from two-way ANOVA (sex × BMI category) are reported. No significant interactions were observed. Bold, p ≤ 0.05; italic, p ≤ 0.10. BMI = body mass index; VO_2max = estimated cardiorespiratory fitness; RMSSD = root mean square of successive differences. Raw RMSSD values are shown in Table 1; RMSSD was natural log-transformed before regression analyses.

	BMI < 25 kg/m^2						BMI ≥ 25 kg/m^2						Male vs Female	BMI < 25 vs BMI ≥ 25
	Male			Female			Male			Female			p-value ω^2 [95% CI]	p-value ω^2 [95% CI]
													0.10 [0.00, 0.27]	**0.44 [0.24, 0.59]**
Resting heart rate (bpm)	69.1	±	4.8	78.3	±	3.9	76.4	±	4.8	76.3	±	2.5	p = 0.27 0.00 [0.00, 0.10]	p = 0.52 0.01 [0.00, 0.00]
RMSSD (ms)	62.3	±	13.2	48.1	±	6.3	46.0	±	7.2	64.6	±	7.9	p = 0.81 0.00 [0.00, 0.00]	p = 0.99 0.00 [0.00, 0.00]
Resting systolic pressure (mmHg)	122.2	±	5.4	107.5	±	8.5	129.0	±	4.3	116.4	±	6.7	*p = 0.09* *0.16 [0.00, 0.54]*	p = 0.31 0.00 [0.00, 0.32]
Resting diastolic pressure (mmHg)	63.8	±	3.8	66.0	±	4.0	76.0	±	6.6	72.8	±	2.0	p = 0.91 0.01 [0.00, 0.00]	**p = 0.04** **0.26 [0.00, 0.61]**
Estimated VO_2max ($mL/kg_{FFM}/min$)	46.5	±	2.0	39.5	±	1.4	45.4	±	3.1	33.6	±	1.3	**p < 0.001** **0.29 [0.10, 0.47]**	*p = 0.07* *0.03 [0.00, 0.17]*

Data are mean ± SEM. Participants were categorized as BMI < 25 kg/m² or BMI ≥ 25 kg/m² for secondary categorical analyses. Main effects from two-way ANOVA (sex × BMI category) are reported. No significant interactions were observed. Bold, p ≤ 0.05; italic, p ≤ 0.10. BMI = body mass index; VO_2max = estimated cardiorespiratory fitness; RMSSD = root mean square of successive differences. Raw RMSSD values are shown in Table 1; RMSSD was natural log-transformed before regression analyses.

In the primary continuous models (Table 2), fat mass was not significantly associated with positive affect after adjustment for sex, age, and estimated VO_2max. In the fully adjusted model, fat mass showed an inverse but non-significant association with positive affect (B = − 0.22, SE = 0.12, p = 0.08). Adding the sex-by-fat mass interaction term did not improve model fit (ΔR^2 = 0.01, p = 0.47), and the interaction term was not significant in the fully adjusted model (B = 0.20, SE = 0.20, p = 0.33). Adding lnRMSSD also did not explain additional variance in positive affect (ΔR^2 = 0.02, p = 0.27), and lnRMSSD was not independently associated with positive affect (B = 0.023, SE = 0.02, p = 0.27).

Table 2
Affect predicted by fat mass

Predictor	Model 1, B, (SE), *p*	Model 2, B, (SE), *p*	Model 3, B, (SE), *p*
Positive Affect			
Sex (male)	1.91 (1.83), p = 0.30	−0.04 (3.22), p = 0.99	−0.52 (3.24), p = 0.87
Age (yrs)	−0.02 (0.20), p = 0.93	−0.03 (0.20), p = 0.88	−0.06 (0.20), p = 0.78
VO_2max (ml/kgFFM/min)	−0.02 (0.11), p = 0.89	−0.03 (0.11), p = 0.82	−0.05 (0.11), p = 0.66
Fat mass (kg)	−0.15 (0.10), p = 0.15	−0.19 (0.12), p = 0.11	−0.22 (0.12), p = 0.08
Sex × Fat mass	--	0.15 (0.20), p = 0.47	0.20 (0.20), p = 0.33
lnRMSSD	--	--	0.02 (0.02), p = 0.27
Model fit (n = 55)			
R^2 (Adj R^2)	0.11 (0.03)	0.12 (0.02)	0.14 (0.03)
RMSE	5.03	5.05	5.04
ΔR^2 (p for change)	--	0.01 (p = 0.47)	0.02 (p = 0.27)
Negative Affect			
Sex (male)	1.71 (1.69), p = 0.32	4.76 (2.94), p = 0.11	4.92 (3.00), p = 0.11
Age (yrs)	−0.38 (0.18), p = 0.05	−0.35 (0.18), p = 0.06	−0.35 (0.19), p = 0.07
VO_2max (ml/kgFFM/min)	−0.08 (0.10), p = 0.45	−0.06 (0.10), p = 0.55	−0.05 (0.10), p = 0.61
Fat mass (kg)	0.19 (0.09), p = 0.05	0.26 (0.11), p = 0.02	0.27 (0.11), p = 0.02
Sex × Fat mass	--	−0.23 (0.18), p = 0.21	−0.25 (0.19), p = 0.20
lnRMSSD	--	--	−0.01 (0.02), p = 0.68
Model fit (n = 55)			
R^2 (Adj R^2)	0.15 (0.08)	0.18 (0.09)	0.19 (0.08)
RMSE	4.65	4.62	4.66
ΔR^2 (p for change)	--	0.03 (p = 0.21)	0.003 (p = 0.68)

Values are unstandardized regression coefficients (B) with standard errors (SE) in parentheses. PA = Positive Affect; NA = Negative Affect; VO_2max = estimated cardiorespiratory fitness; lnRMSSD = natural log-transformed root mean square of successive differences. Sex was dummy-coded with female as the reference group (Sex [Male] = 1, Female = 0). Model 1 included Sex, Age, VO_2max, and Fat mass (kg). Model 2 added the Sex × Fat mass interaction term. Model 3 added lnRMSSD. ΔR^2 reflects the change in explained variance relative to the prior model.

For negative affect, greater fat mass was associated with higher negative affect in the fully adjusted model (B = 0.27, SE = 0.11, p = 0.02). Adding the sex-by-fat mass interaction term did not improve model fit (ΔR^2 = 0.03, p = 0.21), and the interaction term was not significant in the fully adjusted model (B = − 0.25, SE = 0.19, p = 0.20). Adding lnRMSSD did not explain additional variance in negative affect (ΔR^2 = 0.003, p = 0.68), and lnRMSSD was not independently associated with negative affect (B = − 0.01, SE = 0.02, p = 0.68). Together, the continuous models did not detect sex moderation of adiposity–affect associations.

In secondary categorical analyses, a sex-by-BMI-category interaction was observed for positive affect (F[1,51] = 4.15, p = 0.047, ω^2 = 0.053; Fig. 1). Positive affect was similar between females and males in the BMI < 25 kg/m² group, whereas males

reported higher positive affect than females in the BMI ≥ 25 kg/m² group. For negative affect, there were no main effects of sex or BMI category and no sex-by-BMI-category interaction ($F[1,51] = 0.27$, $p = 0.603$, $\omega^2 \approx 0.00$).

Sensitivity analyses using percent body fat instead of fat mass yielded a similar directional pattern but weaker statistical evidence. Sex-by-adiposity interaction terms remained non-significant for positive affect ($\Delta R^2 = 0.01$, $p = 0.46$) and negative affect ($\Delta R^2 = 0.02$, $p = 0.27$), and lnRMSSD was not independently associated with positive affect ($p = 0.26$) or negative affect ($p = 0.71$). The association between percent body fat and negative affect was attenuated and did not reach statistical significance.

These pilot findings suggest that fat mass may be more consistently related to negative affect than to positive affect in healthy young adults. The absence of detected sex-by-fat mass interactions in the primary models does not establish equivalence across sexes, but it does indicate that this small sample did not provide strong evidence for sex moderation when adiposity was modeled continuously. The categorical positive-affect finding should be treated as hypothesis-generating because it was not supported by the primary continuous models.

Limitations

Several limitations should guide interpretation. First, the modest sample size and unequal sex distribution limited precision and reduced power to detect small-to-moderate sex-by-adiposity interactions. The study was better suited to estimating pilot associations than to making definitive claims about sex moderation. Second, the cross-sectional design precludes causal inference and cannot determine whether greater adiposity contributes to negative affect, whether affect influences weight-related behaviors, or whether both reflect shared upstream factors.

Third, participants were recruited from a single university and were screened to exclude diagnosed mental health disorders and major cardiometabolic disease. The findings may not generalize to broader young-adult populations or to individuals with clinical depression, anxiety, obesity-related disease, or other health conditions. Fourth, adiposity and cardiorespiratory fitness were estimated using practical field methods rather than criterion methods such as dual-energy X-ray absorptiometry or directly measured maximal oxygen uptake. Individual-level measurement error should therefore be considered. Fifth, respiratory rate was not directly measured or controlled during heart rate variability acquisition, so RMSSD should be interpreted as an index of short-term resting heart rate variability rather than as a direct measure of vagal tone.

Finally, hormonal contraceptive use, menstrual cycle phase, inflammatory biomarkers, body image, perceived weight stigma, sleep, diet, and other psychosocial variables were not assessed. These factors could plausibly influence adiposity–affect associations or contribute to sex-related heterogeneity. Larger longitudinal studies with more balanced samples and more comprehensive biological and psychosocial phenotyping are needed to determine whether sex-specific moderation is present and to clarify mechanisms.

Abbreviations

BIA
bioelectrical impedance analysis
BMI
body mass index
HRV
heart rate variability
NA
negative affect
PA
positive affect
PANAS

Positive and Negative Affect Schedule
RMSSD
root mean square of successive differences
VO_2max
maximal oxygen uptake

Declarations

Ethics approval and consent to participate

The research protocol was approved by the Chatham University Institutional Review Board (IRB-FY2019-51). All participants provided written informed consent before participation. All procedures were conducted in accordance with the approved protocol and relevant institutional guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

The dataset is not publicly available because the original consent and IRB approval did not include public data sharing. De-identified data are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

EJS and JJD conceived and designed the study. EJS, MAN, SDW, RLP, and JJD performed experiments. EJS and JJD analyzed the data and prepared the figures. EJS, MLC, EJR, JRE, and JJD interpreted the results. EJS and JJD drafted the manuscript. All authors critically reviewed the manuscript, approved the final version, and agreed to be accountable for the work.

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Figures

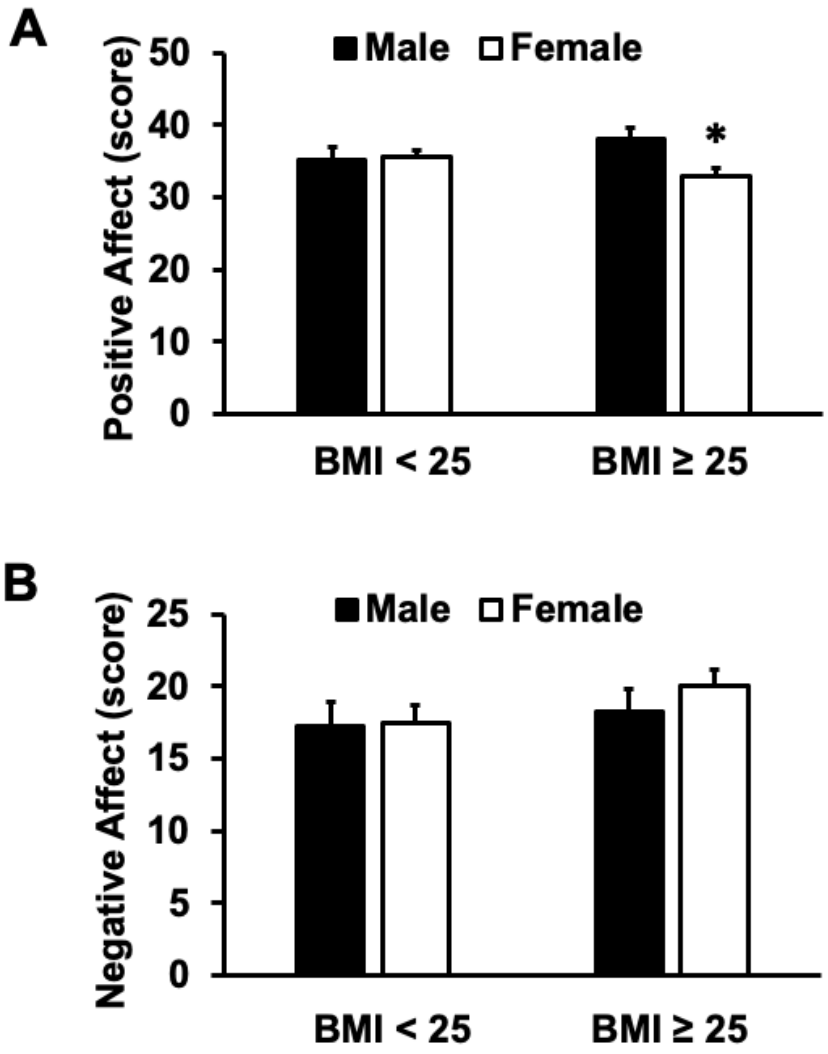


Figure 1

Positive and negative affect by sex and BMI category. Panel A shows positive affect scores from the Positive and Negative Affect Schedule for males and females with BMI < 25 kg/m² and BMI ≥ 25 kg/m². Panel B shows negative affect scores for the same groups. Data are mean ± SEM. *p < 0.05 for the male–female simple contrast within the BMI ≥ 25 kg/m² group following a significant sex × BMI-category interaction for positive affect.