Cognitive Dietary Restraint, Disinhibition, and Hunger are Associated with 24-h Energy Expenditure

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Abstract

**Background:** Higher energy expenditure (EE) is associated with greater food intake, possibly because the human body senses EE and modifies eating behaviors to regulate food intake and ultimately achieve energy balance. As eating behaviors are also influenced by social and cultural factors, any association between EE and eating behavior may differ between ethnicities and sexes.

**Objective:** To assess relationships between EE and eating behavior constructs of the Three-Factor Eating Questionnaire (TFEQ).

**Subjects/Methods:** 307 healthy adults (201M/106F, 160 Native Americans) completed the TFEQ and had measures of 24-h EE in a whole-room calorimeter during energy balance. Body composition was assessed by DXA.

**Results:** On average, adjusted 24-h EE was lower (β=−229 kcal/day, CI: −309−−148, p<0.001) but cognitive restraint (Δ=+1.5; CI: 0.5–2.5, p=0.003) and disinhibition (Δ=+2.1, CI: 1.3–2.8, p<0.001) scores were higher in women compared to men. In Native Americans, adjusted 24-h EE (β=+94 kcal/day, CI: 48–139, p<0.001) and disinhibition scores (Δ=+1.0, CI: 0.1–2.0, p=0.003) were higher compared to other ethnicities. Higher 24-h EE associated with lower cognitive restraint in women (ρ=−0.20, p=0.04), but not men (p=0.71; interaction term p=0.01) with no ethnic differences. Greater 24-h EE associated with higher disinhibition (ρ=0.20, p=0.001) and hunger cues (ρ=0.16, p=0.004) with no gender differences. These associations were primarily
present in non-Native Americans ($\rho=0.23$, $p=0.006$ and $\rho=0.25$, $p=0.003$) but not observed in Native Americans (both $p>0.40$).

Conclusions: Higher EE is associated with psychological constructs of eating behaviors that favors overeating including lower cognitive restraint, higher dietary disinhibition, and greater susceptibility to hungers cues, supporting the existence of energy-sensing mechanisms influencing human eating behavior. These associations were observed in ethnicities other than Native Americans, possibly explaining the contradictory relationships reported between EE and weight change in different ethnic groups. We propose that increased EE may alter eating behaviors, potentially leading to uncontrolled overeating and weight gain.

Keywords
TFEQ; eating behavior; energy expenditure; energy sensing; dietary restraint

Introduction
The complex interplay between energy intake and expenditure (EE) determines daily energy balance and weight change. While energy intake varies considerably from day to day making it difficult to measure, EE is more stable as it largely depends on fat free mass (FFM) and can be accurately measured by indirect calorimetry; therefore, it has been extensively studied in relation to future weight change\textsuperscript{1–5}. However, literature has provided conflicting results on the role of EE in future weight change across different ethnic groups\textsuperscript{6}. Specifically, a relatively lower EE is associated with higher rates of weight gain over time in Native Americans of Southwest descent\textsuperscript{3, 7, 8} whereas the opposite is observed in Blacks\textsuperscript{2}, indicating that ethnic-specific differences influencing the relationship between EE and energy intake may be an important factor in elucidating the role of EE in the etiology of obesity\textsuperscript{6}.

Although energy balance is portrayed as a static regulatory system, daily alterations to one component (EE or energy intake) occur dynamically and may elicit physiological or behavioral compensation in the other component\textsuperscript{6, 9–11}. Consequently, the autoregulatory responses to these perturbations of energy balance would act to regulate energy homeostasis and, in turn, body weight\textsuperscript{6}. Consistent with the hypothesis of a complex interplay between energy metabolism and food consumption, EE is known to correlate strongly with energy intake\textsuperscript{1, 9, 11–15}, supporting the existence of energy sensing mechanisms that may regulate energy intake in humans\textsuperscript{6, 16}, and may ultimately explain inter-individual differences in weight change\textsuperscript{17}. The EE-energy intake link may be driven by the body’s ability to sense EE and consequently alter eating behaviors to meet the body’s energy requirements by modulating energy intake\textsuperscript{9, 11, 12}. Energy intake is often determined by eating behaviors, which in turn are also influenced by social and cultural factors\textsuperscript{18, 19}. Therefore, it is plausible that EE, as an index of energy demands and recently shown to be the main determinant of energy intake\textsuperscript{1, 12, 14, 15}, may be associated with social, cultural, and psychological constructs related to eating behavior, which may ultimately drive energy intake\textsuperscript{9, 11}.  

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The Three-Factor Eating Questionnaire (TFEQ) is a widely used and validated tool for assessing three dimensions of eating behavior, including dietary restraint, disinhibition, and susceptibility to hunger. Associations between cognitive restraint and frequent dieting, lower energy intake and drive for thinness have been reported. Similarly, dietary disinhibition has previously been associated with overeating, loss of control over energy intake, eating in response to emotional distress, as well as greater intake of palatable energy dense foods, often sweet-tasting high-fat food items. Notably, there are strong and consistent associations between disinhibition, obesity and weight gain over time. Moreover, a greater susceptibility to hunger cues has been associated with the orexigenic hormone ghrelin and greater total energy intake.

Higher degree of dietary restraint is associated with relatively lower ad libitum food intake and, in women, restrained eaters have relatively lower EE. Cultural and societal factors related to gender and ethnicity likely influence the eating behavior constructs of the TFEQ and may further explain differing reports of the relationship between EE and weight change in different ethnicities. Given the putative association between EE and eating behaviors as well as the influential role of social and cultural factors on eating behaviors, we hypothesized that the relationship between EE and psychological constructs related to eating behaviors may differ between genders and ethnicities. Therefore, the aims of the current study were to assess the relationships between 24-h EE, as assessed in a whole-room calorimeter during weight maintenance thus representing an adequate measure of daily energy needs, and psychological constructs related to eating behavior, as assessed by the TFEQ, in a large and ethnically diverse cohort, and to investigate any potential differences that exist between genders or ethnicities.

**Subjects and Methods**

The present study represents a secondary analysis of 317 healthy individuals who were recruited from the greater Phoenix area through newspaper and Internet-based advertisement to participate in six different studies (Clinical Trial identifiers: NCT00523627, NCT00342732, NCT00856609, NCT01224704, NCT01237093, NCT00687115) designed to understand the behavioral and metabolic predictors of obesity, including assessment of eating behavior by the TFEQ and 24-h measurements of EE in whole-room indirect calorimeter. Inclusion criteria for the enrollment in these studies were an age range of 18–65 years, while exclusion criteria included diabetes, thyroid disease, hypertension, or cardiovascular disease; pregnancy or use of hormonal contraception. Ethnic groups included the following: 160 Native Americans of Southwestern heritage, 77 Whites, 27 Blacks, 22 Hispanics, and 21 subjects of mixed ethnicity. All participants were found to be healthy based on medical history, physical examinations, and laboratory tests, and had no evidence of active psychiatric illness including eating disorders. Participants were not taking any medications, were nonsmokers, and were excluded if they were not weight stable for the past six months (i.e., variation ≥2.3 kg) or had any significant health problems, including cancer, hypertension, or were current substance abusers. Prior to participation in any study, all volunteers were fully informed of the nature and purpose of the study and written informed consent was obtained. All studies were approved by the Institutional Review Board of the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK).
Upon admission to the clinical research unit, subjects were fed a weight-maintaining diet with a macronutrient distribution of 50% carbohydrate, 30% fat and 20% protein for at least 3 days prior to metabolic testing. Individual weight maintenance calories were initially calculated based on weight, gender and BMI, as previously described, and subsequently adjusted daily by the research dietitian to ensure a body weight within 1% of the admission weight throughout the baseline period. Body composition was determined by dual-energy X-ray absorptiometry (DXA, LUNAR Prodigy, GE). All participants did not have diabetes mellitus based on American Diabetes Association criteria, as determined by a 75g oral glucose tolerance test conducted after at least 3 days on the weight-maintaining diet.

**Three-Factor Eating Questionnaire**

The TFEQ was administered within 48 hours of admission in the morning approximately 1-hour after breakfast. The TFEQ is a 51-item questionnaire that classifies eating behavior on the bases of three factors: cognitive dietary restraint, dietary disinhibition, and susceptibility to hunger. Cognitive restraint reflects the intent to restrict energy intake to control body weight. Disinhibition is the self-reported tendency to overeat in response to various stimuli. Hunger measures an individual’s inclination to eat in response to subjective feelings of hunger. Scores range from 0– 21 (restraint), 0–16 (disinhibition) and from 0–14 (hunger), where higher scores indicate greater disturbances in eating behavior. The TFEQ has demonstrated good internal consistency (Cronbach’s alpha ranging from .79 to .92). Based on established cutoffs, individuals were classified as: restrained (score>10) or unrestrained eaters (0–10), disinhibited (>8) or non-disinhibited eaters (0–8), and susceptible to hunger cues (>7) or not susceptible to hunger cues (0–7).

**Energy expenditure measurement**

The 24-h EE was measured in a whole-room indirect calorimeter (respiratory chamber) during energy balance and after at least 4 days of weight stability, as previously described in detail. The prescribed energy intake for the 24 hours in the respiratory chamber was calculated using unit-specific equations derived to achieve energy balance in this setting. Four meals were provided at 8:00, 11:00, 16:00, and 19:00 through an airlock. Subjects were instructed to eat all food within 30 minutes and to return any uneaten food to metabolic kitchen for adjustment of intake calories. Carbon dioxide production, oxygen consumption, respiratory quotient (RQ), and the rate of EE calculated by the Lusk’s equation were measured continuously, calculated for each 15-minute interval, averaged, and then extrapolated to the 24-hour-interval. Spontaneous physical activity (SPA) was measured by a radar system based on the Doppler Effect and expressed as percentage of time in motion. Sleeping EE was defined as the average EE between 01:00 and 05:00 AM during which SPA was less than 1.5%. The EE in the inactive state (EE0_activity) was calculated as the intercept of the regression line between EE and SPA between 11:00 and 01:00. The awake and fed thermogenesis (AFT), as a measure of the thermic effect of food and the energy cost of being awake, was calculated as the difference between EE0_activity and sleeping EE.
Statistical Analysis

The primary outcome of this study was to assess the relationships between 24-h EE and TFEQ constructs, while the secondary outcome was to assess differences in these relationships according to gender and ethnicity. Alpha was set at 0.05 and 2-sided p-values were reported. All analyses were preplanned and performed using SAS Enterprise Guide (version 7.1) and SPSS (version 25). Normally distributed data are presented as mean±SD, while skewed data are presented as median with interquartile range (IQR). The Chi-squared test was used to assess gender differences across ethnicities. Gender and ethnic differences on average TFEQ scores (Δ) were evaluated by Mann-Whitney U test and Kruskal-Wallis H test, respectively. As there were no differences between TFEQ scores of Blacks, Whites, Hispanics, and mixed ethnicity, these individuals were merged in one group (n=147) and compared to Native Americans (n=160). Two-way ANOVA was used to test the interaction between gender and ethnicity on TFEQ scores. Levene’s test was used to test the homogeneity of variances between groups and, in case of heterogeneous variances, Welch’s ANOVA was conducted in place of ANOVA. Residuals of 24-h EE (adjusted 24-h EE) after adjustments for age, gender, ethnicity, FFM, and fat mass (FM) were calculated via linear regression analysis. Spearman’s rank order correlation was used to quantify associations between TFEQ scores, 24-h EE, and residuals of 24-h EE. Confirmatory analyses were also performed after adjusting 24-h EE for SPA, and results were unchanged so only findings using unaltered/residuals 24-h EE are reported. Linear regression models were used to evaluate the associations between 24-h EE and TFEQ scores, while testing for gender and ethnic differences by including the respective interactions terms. Logistic regression analyses were also performed to test associations between 24-h EE and subgroups (restrained vs unrestrained, disinhibited vs non-disinhibited, and susceptible to hunger cues vs not susceptible) obtained by dichotomizing TFEQ dimensions using established cutoffs22.

Results

Demographic, anthropometric, metabolic, and eating behavior characteristics of the study population are shown in Table 1. Participants were in energy balance during the 24-h EE (mean deviation=0.5%), and the average RQ (=0.86) was similar to the FQ of the balanced diet provided (=0.87)40. On average, women had higher BMI, percent body fat, and FM, but were shorter, had less FFM and lower adjusted 24-h EE (β=−229 kcal/day, 95% CI: −309 to −148, p=5×10−8) compared to men. In terms of ethnic differences, Native Americans had higher body weight, BMI, percent body fat, FM, absolute (β=+219 kcal/day, CI: 136 to 302, p=4×10−7) and adjusted (β=+94 kcal/day, CI: 48 to 139, p=7×10−5) 24-h EE as compared to non-Native Americans. Frequency of genders was similar across ethnic groups (p=0.73).

When participants were categorized according to TFEQ cutoffs (Table 1), restrained and disinhibited subjects were more likely to be women (p=0.04 and p=3×10−5, respectively) with no differences by ethnic group (p=0.28 and p=0.12, respectively), BMI (p=0.62), or body fat (p=0.95). There were no gender (p=0.57) or ethnic (p=0.35) differences in scores of susceptibility to hunger cues. On average, restrained subjects had lower 24-h EE (Δ=−126 kcal/day, CI: −234 to −17, p=0.02) and AFT (Δ=−34 kcal/14·hrs, CI: −69 to −1, p=0.05) but not sleeping EE (p=0.11) or SPA (p=0.65), while subjects who were disinhibited (Δ=+97
kcal/day, CI: −18 to 211, p=0.09) and susceptible to hunger cues (Δ=+95 kcal/day, CI: −10 to 201, p=0.08) tended to have higher 24-h EE.

TFEQ scores: gender and ethnic differences

The average TFEQ scores of cognitive restraint, disinhibition and hunger between genders and ethnic groups are shown in Figure 1, respectively. Cognitive restraint scores were, on average, 23% higher in women compared to men (mean absolute difference, Δ=+1.5, 95% CI: 0.5 to 2.5, p=0.003), with no ethnic differences (p=0.35). No interaction between gender and ethnicity was observed for cognitive restraint (p=0.12). Disinhibition scores were higher in women (Δ=+2.1, 95% CI: 1.3 to 2.8, p=10^−6) and Native Americans (Δ=+1.0, 95% CI: 0.1 to 2.0, p=0.003) compared to men and non-Native Americans, respectively, without any interaction between gender and ethnicity (p=0.07). Cognitive restraint and disinhibition scores were not related in the entire cohort (p=0.74), or separately in women (p=0.17) or men (p=0.62). No gender (p=0.18) or ethnic (p=0.52) differences were observed for hunger ratings.

Relationships between TFEQ scores and 24-h EE

A higher 24-h EE tended to be associated with lower cognitive restraint (ρ= −0.10, p=0.07). However, this inverse relationship was only observed in women (ρ= −0.20, p=0.04, Figure 2A) but not in men (ρ =0.03, p=0.71, Figure 2B; interaction term p=0.01). Similar results were obtained for 24-h EE after adjustment for its known determinants (e.g., body composition, gender, etc.), such that a relatively higher 24-h EE was associated with lower cognitive restraint in women (ρ= −0.24, p=0.01, Figure 2C) but not in men (ρ=0.02, p=0.74, Figure 2D). Both lower restraint (p=0.03) and greater disinhibition (p=0.002) scores were found to be independent predictors of higher 24-h EE in women. There was no ethnic difference in the relationship between 24-h EE and cognitive restraint (interaction term p=0.58). There were no associations between restraint scores and BMI (p=0.26) or body fat (p=0.09).

A greater 24-h EE was associated with higher disinhibition (ρ=0.20, p=0.001) in the whole cohort, and this relationship did not differ between genders (interaction term p=0.44). However, this direct association was driven by non-Native Americans (ρ=0.23, p=0.006, Figure 3A) as no relationship between 24-h EE and disinhibition scores was observed in Native Americans (ρ=0.06, p=0.45, Figure 3B; interaction term p=0.03). Higher hunger cue scores were associated with higher 24-h EE (ρ=0.16, p=0.004) with no differences by gender (interaction term p=0.58). This positive association between 24-h EE and hunger scores was primarily present in subjects not of Native American descent (ρ=0.25, p=0.003, Figure 4A) such as Blacks (ρ=0.46, p=0.02, n=27), but not observed in Native Americans (ρ=0.05, p=0.50, Figure 4B; interaction term p=0.09). Similar positive associations for disinhibition and hunger scores were also found for BMI and body fat, as well as for 24-h EE components including sleeping EE, diet-induced thermogenesis and physical activity-related EE, in ethnicities other than Native Americans but, again, not in Native Americans (data not shown). No associations were found between restraint or disinhibition scores and SPA (all p>0.20). In a multivariate model, higher disinhibition scores (β=+22 kcal/day, p=0.01) and
lower restraint scores ($\beta=-11$ kcal/day, $p=0.04$), but not hunger scores ($p=0.93$), were
independent predictors of 24-h EE in the whole cohort. Similar results were obtained in
women (disinhibition: $\beta=+33$ kcal/day, $p=0.006$; restraint: $\beta=-18$ kcal/day, $p=0.02$), whereas
only disinhibition ($\beta=+55$ kcal/day, $p<0.001$), but not restraint ($p=0.91$) or hunger ($p=0.24$),
was a predictor of 24-h EE in men.

Discussion

We examined the relationships between daily energy needs as quantified by 24-h EE
measured during weight maintenance and psychological constructs related to eating behavior
as assessed by the TFEQ across genders and ethnicities in a large, ethnically diverse cohort.
Individuals with higher daily EE reported higher levels of dietary disinhibition, greater
susceptibility to hunger cues, and possessed less cognitive restraint of eating, suggesting that
cognitive aspects of eating behavior may be partly determined by the underlying
metabolism. However, these associations were highly dependent upon gender and ethnicity.
Specifically, we found an inverse relationship between 24-h EE and cognitive restraint only
in women, who had a relatively lower EE compared to men and were more likely to be
restrained eaters, suggesting that cognitive restraint could be a female-specific learned
behavior in response to lower daily energy needs. Overall, higher 24-h EE was associated
with greater disinhibited eating behavior scores and increased susceptibility to hunger cues;
however, these associations were not present in Native Americans and were primarily
observed in other ethnicities. Thus, the putative behavioral effects exerted by EE on
psychological constructs related to eating behavior may depend on gender, ethnic, or cultural
differences. These gender and ethnic differences may partly explain the contradictory
relationships reported between EE and future weight gain in different ethnic groups, as EE
might alter eating behavior differentially determining daily food intake and ultimately long-
term weight change.

The main aim of the present study was to better understand how EE, recently shown to be
the foremost driver of energy intake in several independent studies $^{1, 12, 14, 27, 41}$, may
regulate food intake via a putative effect on eating behavior as assessed by the psychological
constructs of a well-validated research tool (TFEQ). We observed moderate associations
between lower EE and higher cognitive dietary restraint, as well as between higher EE and
both higher dietary disinhibition and susceptibility to hunger cues. Our current study
provides further evidence on the potential metabolic mechanisms influencing these
constructs of eating behavior. Energy expenditure, which has recently been proposed to be
the main driver of energy intake in humans in multiple independent studies $^{1, 9, 12-14}$, may
influence psychological constructs of eating behaviors, thereby predisposing individuals to
overeating $^{11}$. Specifically, an increased EE might signify an energy-sensing hunger signal
that could alter eating behavior and may lead to greater-than-necessary intake $^{9, 42}$.

Our results show that the relationship between 24-h EE and cognitive restraint is contingent
upon gender and, more importantly, this association was not driven by body size, as neither
BMI nor body fat were associated with restraint scores. In line with previous literature, in
our current study women have higher levels of cognitive restraint as compared to men$^{19, 43}$.
This may be due to the higher rates of dieting, as well as the widespread cultural emphasis.
on a thin ideal body image in women. Our finding that 24-h EE, even after accounting for differences in body size and composition, was inversely associated with restraint in women supports the results from a previous study in lean women, which showed that restrained women had lower energy intake and relatively lower EE compared to unrestrained women. Similarly, restrained eaters with and without a history of dieting had lower resting EE, suggesting that restrained eating may be a behavioral adaptation to a lower EE which supports the hypothesis of energy sensing mechanisms that might drive hunger and appetite. Alternatively, higher dietary restraint may be associated with habitual undereating and negative energy balance that could partly explain the lower EE observed in restrained eaters, although our measures of 24-h EE were obtained in energy balance after at least 4 days of weight maintenance. Nevertheless, given the cross-sectional nature of EE-restraint relationship, future studies including long-term assessments of eating behavior, energy intake and EE are warranted to elucidate the causality of this relationship.

Ethnic and cultural differences may account for difference in psychological constructs of eating behavior and might partly explain the previously reported conflicting associations between EE and weight change, where a relatively lower EE is associated with weight gain in Native Americans but not in other ethnicities. In our current study, a higher EE was associated both with greater dietary disinhibition and with increased susceptibility to hunger cues in those without self-reported Native American heritage. This might provide an explanation for the positive association between higher EE and long-term weight gain reported in populations such as Nigerian adults, as in the current study higher 24-h EE was associated with greater hunger scores in Blacks. In contrast, the absence of associations between 24-h EE and both disinhibition and hunger cues in Native Americans could signify that a higher EE may not be associated with abnormal eating behavior in people of Native American heritage and possibly explain why, in this population, a lower EE is instead associated with weight gain perhaps due to sustained positive daily energy balance caused by a deficit in 24-h EE. It is unclear whether the distinct relationships observed in different ethnicities are due to cultural, environmental, or genetic differences. As dietary disinhibition and hunger cues are consistently associated with overeating, it is possible that in certain populations the mechanism of overconsumption and sustained positive energy balance may occur via an effect of an internal sensing of higher EE on eating behaviors. Nevertheless, as no measures of free-living energy intake were available in the current study, future studies including actual measures of food intake and habitual eating behavior are warranted to demonstrate this energy-sensing mechanism.

Our study has several strengths including a large sample size, a highly diverse ethnic composition, and precise measurements of EE for 24 hours during energy balance and weight maintenance which likely reflects daily energy needs; nevertheless, it also has some important limitations including multiple testing which might have led to an inflated Type I error rate. Nonetheless, the main results of our primary research questions (i.e., the relationships between 24-h EE and the three TFEQ constructs) have p-values that meet the stringent Bonferroni’s threshold of 0.0167 calculated based on three independent tests (e.g., the unadjusted p-values for 24-h EE vs. disinhibition and hunger scores were 0.001 and 0.004, respectively). Nevertheless, as this study represents an exploratory analysis of the relationships between 24-h EE and TFEQ constructs, the current results need to be...
confirmed in confirmatory studies done in ethnically cohorts, including the formal validation of TFEQ in Native Americans which is currently lacking. The average BMI was in the obese range (≥ 30 kg/m²) which may have led to a bias in quantifying the associations between EE and eating behavior constructs that can be confounded or blunted by adiposity. Yet, in this overweight cohort, we were still able to detect moderate associations for EE and replicate the previously reported association observed in restrained women¹⁸, without observing any association between restraint scores and measures of body size such as BMI or body fat. Further, our study lacks measures of habitual physical activity, which is an established determinant of eating behaviors and food intake⁴⁷–⁴⁹. Further, we did not have measure of energy intake in free-living conditions and were therefore not able to demonstrate that TFEQ constructs related to eating behavior may influence energy intake in real-life settings, although previous studies have shown consistent associations between TFEQ scores and energy intake¹⁴, ⁵⁰, ⁵¹. Lastly, the recruiting method may have biased our findings based on cross-sectional associations, thus the casual relationships between EE and TFEQ constructs could be ascertained with current data that also do not include a control group. Therefore, intervention studies including manipulation of EE and subsequent measurement of eating behavior in intervention vs. control groups are warranted to elucidate the causality of these relationships. However, the present analysis that constitutes the largest study assessing the relationships between psychological constructs related to eating behaviors by the widely used TFEQ and EE using 24-h measures by a highly precise and reproducible method of indirect calorimetry, will serve as a basis to develop future studies that should take into account both gender and ethnicity as important factors in their design.

In summary, we observed that individuals with higher 24-h EE reported lower cognitive restraint, higher disinhibited eating, and greater susceptibility to hunger cues, all features likely associated with a propensity to overeating. However, these relationships were dependent upon gender and ethnicity. That is, women with relatively lower 24-h EE were more likely to be restrained eaters suggesting that dietary restraint may be a learned behavior to lower daily energy needs. Furthermore, higher 24-h EE was associated with self-reported increased disinhibited eating and susceptibility to hunger cues, but these associations varied by ethnicity. Our present results support recent findings implicating EE as the main determinant of energy intake, and suggest that EE may influence eating behavior in humans. Indeed, the observed associations between 24-h EE and psychological constructs related to eating behaviors may constitute one of the energy sensing mechanisms, which ultimately determines the propensity of one individual to weight gain.

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**Abbreviations:**

| Abbreviation | Description                   |
|--------------|-------------------------------|
| AFT          | awake and fed thermogenesis   |
| EE           | Energy Expenditure            |
| FFM          | fat free mass                 |
| FM           | fat mass                      |
| SPA          | spontaneous physical activity  |
| TFEQ         | three-factor eating questionnaire |

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Figure 1.
(A) Women had higher cognitive restraint and disinhibition scores as compared to men, and
(B) Native Americans had higher disinhibition scores as compared to other ethnicities. Error
bars represent 95% confidence interval of the mean. Δ: mean difference between groups.
Figure 2.
Higher 24-h EE was associated with lower dietary restraint in women (A) but not men (B). Higher residual 24-h EE (adjusted for age, gender, ethnicity, FFM and FM) was associated with lower dietary restraint in women (C) but not men (D). In each panel, the Spearman’s correlation coefficient ($\rho$) is reported along with its significance ($p$). The best-fit line is displayed in each panel.
Figure 3.
Higher 24-h EE was associated with higher dietary disinhibition in non-Native Americans (A) but not in Native Americans (B). In both panels, the Spearman’s correlation coefficient ($\rho$) is reported along with its significance ($p$). The best-fit line is displayed in both panels.
Figure 4.
Higher 24-EE was associated with greater susceptibility to hunger cues in non-Native Americans (A) but not in Native Americans (B). In both panels, the Spearman’s correlation coefficient ($\rho$) is reported along with its significance ($p$). The best-fit line is displayed in both panels.
Table 1.
Participant demographic, anthropometric, metabolic, and eating behavior characteristics in men (n = 201), women (n = 106) and in Native Americans (n = 160) and Other Ethnicities (n = 147)

| Variable                      | All    | Men       | Women     | Native Americans | Other Ethnicities | Restrained eaters |
|-------------------------------|--------|-----------|-----------|------------------|-------------------|-------------------|
| n                             | 307    | 201       | 106       | 160              | 147*              | 59                |
| Age (years)                   | 35.1 ± 9.7 | 35.6 ± 9.6 | 34.2 ± 9.9 | 34.2 ± 8.8       | 36.0 ± 10.6       | 35.8 ± 9.8        |
| Body weight (kg)              | 92.1 ± 22.4 | 91.9 ± 22.0 | 92.3 ± 23.2 | 95.1 ± 22.5      | 88.8 ± 21.9*      | 88.6 ± 20.9       |
| Height (cm)                   | 170 ± 9 | 175 ± 7   | 163 ± 5*   | 169 ± 8          | 172 ± 9*          | 169 ± 10          |
| BMI (kg/m²)                   | 31.8 ± 7.9 | 30.2 ± 7.1 | 34.9 ± 8.4* | 33.4 ± 7.9       | 30.0 ± 7.5*       | 31.3 ± 7.4        |
| Body fat (%)                  | 30.7 ± 9.1 | 26.3 ± 7.1 | 39.2 ± 5.9* | 32.7 ± 8.0       | 28.6 ± 9.7*       | 30.6 ± 10.0       |
| Fat mass (kg)                 | 29.4 ± 13.5 | 25.3 ± 11.8 | 37.2 ± 13.3* | 32.0 ± 13.1      | 26.6 ± 13.5*      | 27.8 ± 12.6       |
| Body free mass (kg)           | 62.7 ± 12.5 | 66.7 ± 11.6 | 55.1 ± 10.6* | 63.1 ± 12.9      | 62.2 ± 12.2       | 60.8 ± 13.5       |
| Fasting glucose (mg/dL)       | 93.4 ± 8.5 | 93.3 ± 8.5 | 93.5 ± 8.7 | 93.2 ± 9.5       | 93.7 ± 7.4        | 94.9 ± 9.2        |
| 2-h glucose (mg/dL)           | 124 ± 30 | 122 ± 29  | 128 ± 31  | 127 ± 30         | 120 ± 29          | 126 ± 31          |
| 24-h INTAKE (kcal/day)        | 2265 ± 344 | 2367 ± 292 | 2072 ± 354* | 2276 ± 347       | 2254 ± 342        | 2176 ± 333        |
| 24-h EE (kcal/day)            | 2278 ± 384 | 2382 ± 370 | 2080 ± 330* | 2383 ± 377       | 2164 ± 359*       | 2177 ± 391        |
| 24-h RQ (ratio)               | 0.86 ± 0.04 | 0.85 ± 0.04 | 0.86 ± 0.04 | 0.85 ± 0.04      | 0.86 ± 0.04       | 0.86 ± 0.04       |
| 24-h energy balance (kcal/day) | −13 ± 286 | −15 ± 283 | −8 ± 293  | −107 ± 268       | 91 ± 271*         | −1 ± 244          |
| 24-h energy balance (% of 24-h EE) | 0.5 ± 12.6 | 0.6 ± 12.0 | 0.4 ± 13.8 | −3.8 ± 11.2      | 5.2 ± 12.4*       | 1.1 ± 11.5        |
| Sleeping EE (kcal/day)        | 1695 ± 271 | 1764 ± 259 | 1565 ± 244* | 1736 ± 273       | 1652 ± 262*       | 1652 ± 280        |
| Spontaneous physical activity (%) | 7.0 ± 4.5 | 6.1 ± 5.7 | 6.7 ± 4.9  | 7.2 ± 5.3        | 6.1 ± 4.5          | 6.0 ± 3.9         |
| EEo activity (kcal/14-hrs)    | 1320 ± 219 | 1386 ± 207 | 1195 ± 187* | 1339 ± 228       | 1300 ± 209        | 1262 ± 222        |
| Awake and fed thermogenesis (kcal/14-hrs) | 331 ± 119 | 357 ± 121 | 282 ± 98* | 327 ± 128        | 336 ± 108          | 303 ± 120         |
| TFEQ                          |         |           |           |                  |                  |                  |
| Cognitive Restraint (score)   | 6.9 ±4.2 | 6.4 ±4.0  | 7.9 ± 4.2* | 6.7 ± 3.8        | 7.2 ± 4.5         |                  |
| Restrainted eaters (n)        | 59 (19%) | 32 (16%)  | 27 (25%)*  | 27 (17%)         | 32 (22%)          |                  |
| Disinhibition (score)         | 5.0 ± 3.3 | 4.3 ± 2.8 | 6.3 ± 3.7* | 5.2 ± 2.8        | 4.7 ± 3.8*        |                  |
| Disinhibited eaters (n)       | 52 (17%) | 21 (10%)  | 31 (29%)*  | 22 (14%)         | 30 (20%)          |                  |
| Hunger Cues (score)           | 4.7 ± 3.3 | 4.5 ± 3.2 | 5.0 ± 3.4  | 4.7 ± 3.1        | 4.6 ± 3.5         |                  |
| Susceptible to hunger cues (n) | 64 (21%) | 40 (20%)  | 24 (23%)  | 30 (19%)         | 34 (23%)          |                  |

Data are presented as mean±SD.

*boldface indicates significant differences (p < 0.05) between groups as assessed by Students t-test, Mann-Whitney U test (for TFEQ scores), or Chi-squared test.

#77 Whites, 27 Blacks, 22 Hispanics, and 21 subjects of mixed ethnicity.

Individuals were classified according to TFEQ cutoff values as: restrained (score>10), disinhibited (>8), and susceptible to hunger cues (>7).