HHS Public Access
Author manuscript
Physiol Behav. Author manuscript; available in PMC 2021 November 27.

Published in final edited form as:
Physiol Behav. 2021 November 01; 241: 113562. doi:10.1016/j.physbeh.2021.113562.

The Effects of Acute Exercise on Appetite and Energy Intake in Men and Women

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Abstract

PURPOSE: To compare energy intake (EI) and appetite regulation responses between men and women following acute bouts of aerobic (AEx), resistance exercise (REx), and a sedentary control (CON).

METHODS: Men and women (n=24; 50% male) with overweight/obesity matched on age (32.3±2 vs. 36.8±2 yrs, p=0.14) and BMI (28.1±1.2 vs 29.0±1.5 kg/m2, p=0.64) completed 3 conditions: 1) AEx (65-70% of age-predicted maximum heart rate for 45 min); 2) REx (1-set to failure on 12 exercises); and 3) CON. Each condition was initiated in the post-prandial state (35 minutes following consumption of a standardized breakfast). Appetite (visual analog scale for hunger, satiety, and prospective food consumption [PFC]) and hormones (ghrelin, PYY, and GLP-1) were measured in the fasted state and every 30 minutes post-prandially for 3 hours. Post-exercise *ad libitum* EI at the lunch meal was also measured.

RESULTS: Men reported higher levels of hunger compared to women across all study conditions (AEx: Men: 7815.00 ± 368.3; Women: 5428.50 ± 440.0 mm x 180 min; p=0.025; REx: Men: 7110.00 ± 548.4; Women: 6086.25 ± 482.9 mm x 180 min; p=0.427; CON: Men: 8315.00 ± 429.8; Women: 5311.25 ± 543.1 mm x 180 min; p= 0.021) and consumed a greater absolute caloric load than women at the *ad libitum* lunch meal (AEx: Men: 1021.6 ± 105.4; Women: 851.7 ± 70.5 kcals; p=0.20; REx: Men: 1114.7 ± 104.0; Women: 867.7 ± 76.4 kcals; p=0.07; CON:

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CONFLICTS OF INTEREST:
The authors declare no conflicts of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

Men: 1087.0 ± 98.8; Women: 800.5 ± 102.3 kcals; p= 0.06). However, when adjusted for relative energy needs, there was no difference in relative *ad libitum* EI observed between men and women. No differences in Area Under the Curve for Satiety, PFC, ghrelin, PYY, and GLP-1 were noted between men and women following acute exercise (all p>0.05).

CONCLUSIONS: These data suggest that women report lower ratings of appetite following an acute bout of exercise or sedentary time when compared to men, yet have similar relative EI. Future work is needed to examine whether sex-based differences in appetite regulation and EI are present with chronic exercise of differing modalities.

Keywords

eating behaviors; appetite regulation; sex-based differences; resistance exercise

1. INTRODUCTION

Obesity continues to be a prevalent issue worldwide (1). Because obesity increases the risk of many co-morbidities that influence quality of life and mortality (2-4), it is crucial for research to be focused on its attenuation and mitigation. Dynamic energy balance models in which homeostatic physiologic mechanisms and hedonic behavioral mechanisms involving appetite control are activated can provide insight into the central mechanism in weight gain and weight loss, (5, 6). It has been suggested that in diet-induced weight loss, both homeostatic and hedonic behavioral appetite regulators shift in a manner that promotes energy intake (EI)(7, 8) However, exercise-induced energy deficits have been shown to attenuate the anticipated increase in appetite and EI following weight loss(9, 10). This suggests exercise as a strategy to dampen the appetite-related physiological and behavioral effects of weight loss(11, 12), though these effects have been shown to vary from person to person(13).

Sex-based differences have been known to exist in the modulation of appetite control following both diet-induced and exercise-induced energy deficits (14). Past research suggests women compensate for exercise induced energy deficits by increasing EI and/or decreasing non-exercise energy expenditure to a greater extent than men(14-17). These findings are supportive of the paradigm that biological protective mechanisms of body composition are stronger in women than they are in men in order to preserve reproductive function(18).Yet, comparisons between men and women regarding the effects of exercise on appetite regulation and EI have produced conflicting results(19-24).

Acute aerobic exercise (AEx) interventions in men and women have shown conflicting results. Some trials report no effect(20, 21) while others result in increased circulating PYY in men when compared to women(22). Acute resistance exercise (REx) has been less well studied, yet is an intervention of interest as it has shown to increase PYY and GLP-1(25-27). Furthermore, REx leads to favorable alterations in body composition which have may affect the tonic control of appetite and EI, leading to modulations in appetite regulation(28). While additional research is needed into how AEx and REx influence appetite regulation in men and women, even less is known regarding individuals who have overweight/obese (OW/OB), as the majority of past research has been in lean, healthy individuals.

Therefore, the purpose of this study was to compare the effects of an acute bout of REx, AEx, and a sedentary control (CON) condition on hormonal and behavioral indices of appetite regulation and EI in men and women with OW/OB.

2. METHODS

2.1 Participants

Twenty-four adults (12 men, 12 women) with OW/OB participated in this trial (Table 1). Men and women were matched on age and BMI. Participants were recruited on the basis that they were weight stable (<±5% in the past 6 months) and physically inactive (not meeting current ACSM physical activity guidelines of 150 min/week of moderate-intensity activity and 2x/week whole-body resistance exercise, based on self-report), and otherwise healthy. Women that reported irregular menstrual cycles, were currently pregnant, lactating, or less than 6 months post-partum were excluded, as well as women who were or peri- or post-menopausal. Inclusion was based on self-reported biological sex. Testing days for male participants were separated by a 7-day washout period. Testing days for female participants were separated by a 1-month washout period to ensure all testing sessions occurred during the follicular phase (days 1-10) of the menstrual cycle. Participants provided written informed consent prior to participation. The study protocol was approved by the Colorado Multiple Institutional Review Board.

2.2 Study Design

This study was a secondary analysis of a previously conducted trial investigating the effect of modality of exercise on appetite and energy intake(29). Participants were first asked to completed baseline evaluations including height, weight, body composition via dual energy x-ray absorptiometry (DEXA; Hologic Discovery W, Bedford, MA), and the Three-Factor Eating Questionnaire (TFEQ) (30) to evaluate dietary restraint, disinhibition, and hedonic hunger. Participants were then asked to complete four exercise familiarization sessions (two for REx and two for AEx) over the course of two weeks to learn the proper use of exercise equipment and to allow for individualized exercise prescriptions to be determined for the REx and AEx study interventions. Specifically, the proper resistance was identified for the REx trial to allow for participants to perform 1-set to failure (e.g., 12-15 repetitions with a RPE of 9-10 on a 10-point scale on final reps) on 12 exercises targeting all major muscle groups, with a 3-minute rest between exercises. The intensity in the AEx intervention was identified via heart rate (HR). Participants were familiarized and fitted with a chest-worn HR monitor and asked to walk on a treadmill for 45 minutes (5-min warm-up, 35-min workout, and 5-min cool-down) at 65-70% age-predicted HR max(31). There was not a familiarization session for the CON condition (45 minutes of quiet rest). These protocols were chosen because they result in a decreased participant burden by negating the need to perform maximal testing prior to study testing days. Additionally, the chosen protocols adhere to current ACSM guidelines, specifically for individuals who are physically inactive or recreationally active.(31)

Participants were then assigned, in a randomized order, stratified by sex, to the REx study day, AEx study day, and CON study day. Individualized 1-day run-in diets preceded each study day visit to ensure energy and macronutrient balance. The caloric value of the individualized diets was determined using the Mifflin-St. Joer equation multiplied by an activity factor of 1.3; the macronutrient composition was 20% protein, 30% fat, and 50% carbohydrate. The Colorado Clinical and Translational Research Center (CTRC)'s metabolic kitchen prepared all food. Participants were provided with the individualized 1-day run-in diet and instructed to only consume the food provided; adherence was confirmed the following day.

Participants presented to the outpatient CTRC in the morning after their 1-day run in diet and overnight fast of at least 10 hours. Participants were asked to refrain from alcohol consumption for the prior 24-hours and from exercise for the prior 48-hours to the study day visit. Upon arrival, an intravenous (IV) catheter was inserted for serial blood sampling. A fasting blood sample was taken for analysis of ghrelin, PYY, and GLP-1. Participants also completed fasting appetite evaluations measured by 100 mm visual analogue scales (VAS). These evaluations included ratings of hunger, satiety, and prospective food consumption (PFC), as previously described(32). Participants then consumed their individualized breakfast within 15 minutes. The caloric content of the breakfast meal was equal to 25% of each participant's total daily requirement and had an identical macronutrient composition to the run-in diet. Breakfast meals differed slightly depending on the caloric needs of the participants in order to ensure the same relative caloric value. However, these meals typically consisted of scrambled eggs, toast with butter, fruit, and yogurt. Blood draws and appetite ratings were repeated 30, 90, 120, 150, and 180 minutes after the breakfast meal. Participants began their assigned 45-minute exercise (or CON) session following the 30-minute blood draw and appetite rating. Participants were asked to complete the Food Craving Inventory (FCI) Inventory(33) questionnaire at the 90-minute assessment point. At the 180-min timepoint, the final blood draw and appetite ratings were completed, and participants were then offered an 1800-calorie buffet style lunch to evaluate *ad libitum* EI. Specifically, the buffet style lunch consisted of lasagna, dinner rolls, butter, cheese, salad, salad dressing (a ranch and a vinaigrette option), pound cake, strawberries, regular soda, and a diet soda. Participants were given a 30-minute time limit in a private room to consume as much of the lunch meal as they wished and were able to leave when finished.

The CTRC Core Laboratory measured total ghrelin (Millipore) and PYY (Millipore) using radioimmunoassays, and GLP-1 (Mercodia) using ELISA. Area Under the Curve (AUC) was calculated for all outcome variables using the trapezoid method(34).

2.3 Statistical Analysis

Lab data are available for n=23 (12 men, 11 women) participants for AEx and CON visits, and n=22 (12 men, 10 women) participants for REx visits; due to inability to obtain catheter access in all participants. Body composition and GLP-1 data are available for n=19 (10 men, 9 women) participants. Lastly, an additional participant did not have 180-minute bloodwork and AUC at the REx visit due to the IV catheter failing prior to that time point. Data were analyzed using R Studio version 1.2.5033 (Vienna, Austria, 2020). Descriptive univariate analyses were conducted on all study variables. Mixed factorial ANOVA's were used to assess AUC for total ghrelin, PYY, GLP-1, prospective food consumption, and hunger. The primary pairwise comparison of interest was men vs. women. Post-hoc independent t-tests were used in order to determine differences between men and women in each condition. Post- hoc one-way ANOVAs were used to test for differences between conditions within each sex. Sensitivity analysis was conducted using G*Power to determine the effect size this fixed sample size had the statistical power to detect.(35) Significance for all statistical tests was set at $P < 0.05$. Data are reported as means and standard errors unless otherwise noted.

3. RESULTS

3.1 Participant Characteristics

12 men and 12 women (total n=24) participated in this trial. Baseline characteristics are presented in Table 1. While BMI did not differ between men and women, as expected body fat percentage was higher in women when compared to men (Men: 30.6 ± 2.1%; Women: 40.1 ± 1.3%; p = 0.01). 41.7% of women were on hormonal contraceptives (n=5). There were no statistical differences in TFEQ data between men and women (Table 1).

3.2 Ad libitum EI

As anticipated, men consumed a greater absolute caloric load than women at the *ad libitum* lunch meal in all experimental sessions (Mixed Factorial: Men: 1074.4 ± 348.0 kcals; Women: 840.0 ± 285.0 kcals; sex: p=0.06; Post-hoc: AEx: Men: 1021.6 ± 105.4; Women: 851.7 ± 70.5 kcals; p=0.20; REx: Men: 1114.7 ± 104.0; Women: 867.7 ± 76.4 kcals; p=0.07; CON: Men: 1087.0 ± 98.8; Women: 800.5 ± 102.3 kcals; p= 0.06). However, when based upon relative energy needs, energy intake did not differ between men and women in any of the experimental sessions (data are presented in Table 2). There were no statistical differences between men and women in FCI scores across conditions (p>0.05). Within each sex, there was no statistical difference across conditions in absolute caloric intake, relative caloric intake, and FCI scores(all p>0.05).

3.3 Subjective Appetite Ratings and Cravings

Appetite ratings for men and women are shown in Figure 1. There was a main effect of sex for hunger AUC (p=0.02). Post-hoc analysis revealed that this effect was driven by significant differences between men and women in the AEx and CON conditions sessions (all data shown in Table 2). Post-hoc sensitivity analysis revealed the sample size to have 80% statistical power to detect effects of 1.3. The effect size of hunger AUC was determined to be 0.77. There were no main effects of sex, or condition, nor was there any sex by condition interactions observed in satiety AUC (all p> 0.05; Table 2). There was a trend towards significance for the main effect of PFC (p= 0.06). Post-hoc analysis showed there to be significant differences between PFC in men and women following the AEx and CON conditions (CON: p=0.03; AEx: p=0.04 ; REx: p=0.57; Table 2). The effect size of PFC AUC was determined to be 0.70. Within each sex, there were no statistical differences across conditions in all subjective appetite ratings and cravings (all p>0.05).

3.4 Ghrelin, PYY, and GLP-1

Figure 2 and Table 2 display ghrelin, PYY, and GLP-1 concentrations in men and women for each study condition. There were no statistically significant differences between men and women, nor were there any sex by condition differences in these appetite-related hormones (all $p > 0.05$).

4. DISCUSSION

This study examined sex-based differences in appetite regulation following acute aerobic and resistance exercise as compared to sedentary control in in physically inactive men and women with OW/OB. Despite there being no statistical differences in gut peptide AUC concentrations or relative *ad libitum* EI between men and women, our results show hunger ratings to be higher in men when compared to women.

Men reported higher overall feelings of hunger after all experimental sessions when compared to women. These differences in hunger between men and women were observed to be strongest in the AEx and CON sessions. Although there were no statistically significant differences within each sex across conditions, interestingly, men reported the highest levels of hunger in the CON condition, attenuated hunger in the AEx condition, and the lowest levels of hunger in the REx. Women reported highest levels of hunger in the REx condition, attenuated hunger in the AEx condition, and the lowest levels of hunger in the CON condition. These results suggest acute exercise to have a potential anorexigenic effect on men and orexigenic effect on women. This finding contributes to the body of literature demonstrating weight protective responses to be stronger in women when compared to men following exercise-induced energy deficits(14-17). Further, the REx session appeared to have the most discrepant effect between men and women. Due to the limited research investigating the effects of REx on appetite response and EI in men and women, it is difficult to contextualize these findings. Thus, these data strongly indicate that further research into the effects of REx on appetite regulation and EI in men and women is warranted.

These differences in hunger, however, were in the setting of similar relative EI in men and women. Therefore, these results suggest women to have higher EI in relation to their feelings of hunger when compared to men, implying divergent eating behaviors following both acute exercise and sedentary time. This could be characterized as a dysregulated relationship between appetite and EI in women. This is noteworthy considering that past research proposes women to more precisely match, or overcompensate, EI with energy expenditure when compared to men, who typically do not sufficiently increase EI to balance exercise-induced energy deficit (15, 36, 37). Thus, the findings from our study support the presence of divergent appetite regulation following acute exercise in men and women.

Despite differences in appetite ratings, as mentioned above, *ad libitum* EI did not differ between men and women. These results are in line with prior work investigating EI following acute exercise(20, 21, 38). To our knowledge, there have not been studies specifically comparing EI between men and women with OW/OB following an acute bout of AEx, REx, and CON. One study by Douglas et al. compared men and women with OW/OB to lean individuals following 60 minutes of aerobic exercise and reported no difference in EI between OW/OB and lean groups (p=0.41) or group by intervention interactions (p=0.60)(38). Therefore, we believe our results extend prior findings that an acute bout of exercise does not affect EI in the hours following exercise in both men and women with OW/OB. However, there is past research that demonstrates that chronic exercise modulates EI, and it is possible that energy compensation happens in the days or weeks following exercise(36, 37). This was demonstrated in a study by Stubbs et al., who conducted two studies investigating the effects of graded levels of exercise on EI and balance, one in men and another in women(36, 37). Although these studies differed slightly in their study design, these studies showed that women compensated for 33% of their energy expenditure with increased EI over the course of 7 days (37), while men did not show compensatory increases in EI (36). Based on these past data, and our current results, we propose that changes in EI between men and women do not happen in response to a single bout of exercise, rather they may occur after multiple days of exercise.

Results from this study did not support our hypothesis that women would exhibit concentrations of appetite-related hormones in a manner to suggest appetite-stimulation when compared to men. Considering the past research in this area (20, 39), it is likely that our results are explained by the study duration. For example, one study by Hagobian et al. reported women with OW/OB respond to exercise with higher acylated ghrelin and lower insulin, suggestive of appetite stimulation, when compared to men with OW/OB following four days of consecutive exercise (19), supporting the paradigm that appetite and EI may be stimulated to a higher degree in women to compensate for energy deficits and protect body fat for reproductive health.

Studies of sex differences in the hormonal control of appetite following acute exercise in lean adults has produced conflicting results, some suggest hormonal responses suggestive of increased satiation in men when compared to women (22, 23), while others report no differences (20, 21). The results of the current study, however, did not reveal any divergence in the biological homeostatic control of appetite between men and women with OW/OB following acute exercise. Although, our results did show energy regulating hormones to be impacted by study intervention (AEx, REx, CON), regardless of sex. These results are reported in detail elsewhere(29).

By virtue of studying sex-based differences in the behavioral and hormonal control of appetite, it is also important to consider the cyclical changes in female sex hormones that are known to affect and influence appetite, appetite-related hormones, and EI throughout the menstrual cycle(40). We sought to control for this by asking women to complete their exercise sessions during the follicular phase (days 1-10) of their menstrual cycle and implementing a 28-day washout period between study interventions for women. Additionally, this study included women who were on hormonal contraceptives, therefore we must acknowledge that the results from this study may not be generalizable to women who are not taking contraceptives. Furthermore, we acknowledge that there are many nuances to the menstrual cycle. Future research should be done in women with and without regular menstrual cycles, as well as in women with variable endogenous and exogenous hormonal statuses, across the lifespan.

Despite the strengths of this study, including a strong randomized cross-over design, dietary control, and direct measurement of EI, this study is not without limitations. First, energy expenditure was not matched between the AEx and REx conditions, nor was energy expenditure measured in the AEx, REx, or CON conditions. Instead, we chose to match the interventions on duration, reflecting a more practical utility. Thus, this study design does not address the possibility of likely divergent regulatory appetite and EI outcomes due to differences in the energy expenditure of each modality of exercise. Second, this study was not comprehensive in the analysis of energy regulation and intake behaviors, and we acknowledge that we did not evaluate all hormonal or behavioral indices of appetite and EI. We suggest future work to extend the assessment of appetite and EI through the remainder of the day and into the following day(s). Furthermore, we acknowledge that since participants knew the purpose of the study was to evaluate hormones related to appetite, they likely were able to deduce that we were also measuring their food consumption. Thus, self-reported appetite ratings and EI at the *ad libitum* lunch meal may have been influenced by social desirability bias. Third, we acknowledge compensations in EI following the study visit, which was not measured, could have occurred. Fourth, we recognize that *ad libitum* or buffet-style meals are not necessarily indicative of how individuals eat in a normal setting as these types of meals are known to result in greater EI as a result of excess calories provided(41). Lastly, we acknowledge that because this study was hypothesis generating and an exploratory sub aim of the original study there was not *a priori* effect size calculation conducted and we were therefore underpowered in our analysis. Post-hoc sensitivity analysis revealed our sample size to have 80% statistical power to detect sex-specific effect sizes of 1.2, however, our effect sizes were not that large. Nonetheless, our findings suggest the directionality of hunger ratings following exercise to differ between men and women. While not statically significant, these data are intriguing and warrant future, larger-scale investigation into the potential orexigenic effects of exercise in women and anorexigenic effects in men.

5. CONCLUSION

Our results indicate women to display behaviors indicative of orexigenic effects of exercise, while men display indications of anorexigenic effects of exercise. Additionally, women report lower feelings of hunger following an acute bout of exercise when compared to men, yet have similar levels of relative EI. These results suggest 1) stronger weight protective mechanisms to be present in women when compared to men and 2) women to have discrepancies between perceived hunger and subsequent EI when compared to men. The results of this study suggest further research into the behavioral mechanisms of EI in women when compared to men, including direct measurements of energy expenditure during exercise and assessment of appetite and EI following acute exercise, particularly following REx, to determine if appetite control differs in men and women for the remainder of the day or the following day(s). Past research suggests women to have weight protective responses to energy deficits and exercise in order to protect reproductive function. The results from this study propose a behavioral mechanism that adds to our understanding of that paradigm and thus provides insight into the regulation of appetite in men and women.

ACKNOWLEDGEMENTS:

This work was supported by the National Institutes of Health Grant Numbers: NIH/NCATS under award numbers UL1TR002535, 1UL01TR002538, KL2TR002539, NIDDK P30DK048520, NIH/NIDDK Grant T32DK07658 and T32DK007446. This work was also supported by a pilot grant award from the University of Colorado's Center for Women's Health Research. This trial was pre-registered at clinicaltrials.gov (NCT03143868). The manuscript content are the authors' sole responsibility and do not necessarily represent official NIH views. Drs. Melanson and Cornier are supported by resources from the Geriatric Research, Education, and the Clinical Center at the Denver VA Medical Center. The contents do not represent the views of the U.S. Department of Veterans Affairs or the United States Government. We thank Dr. Keith Lohse for assistance with the statistical analysis of the data collected in this trial. acknowledge and thank the University of Colorado's Clinical and Translational Research Center for their support in conducting this trial.

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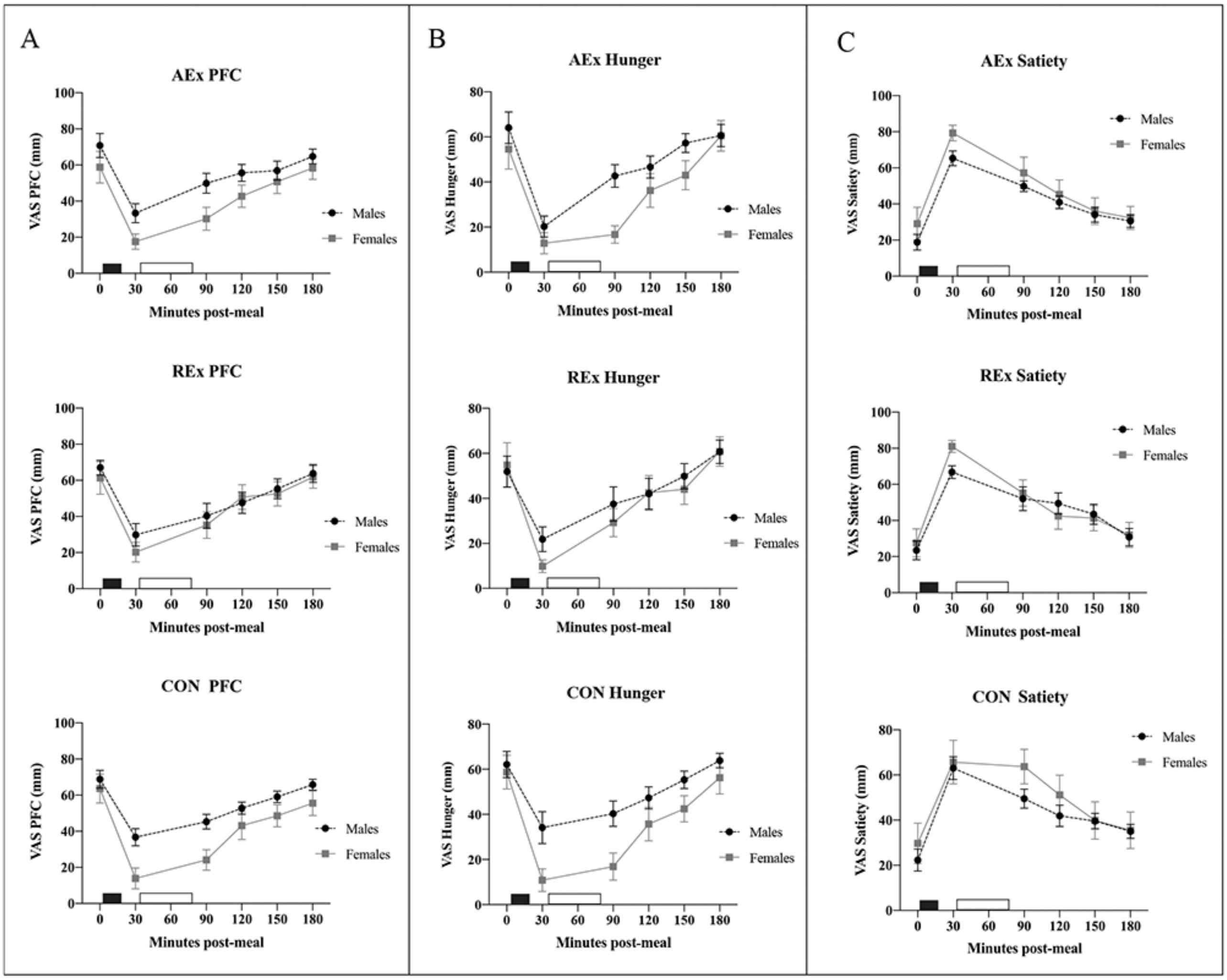

Fig. 1.

Appetite Ratings in Men and Women. Curves for Appetite Ratings (A: Prospective Food Consumption (PFC) B: Hunger C: Satiety) in Men and Women in the AEx, REx, and SED study conditions. Data are presented as mean ± SE; Black rectangle indicates standardized breakfast; Open rectangle indicates study intervention; VAS: visual analogue scale; REx: resistance exercise; CON: sedentary control; AEx: aerobic exercise.

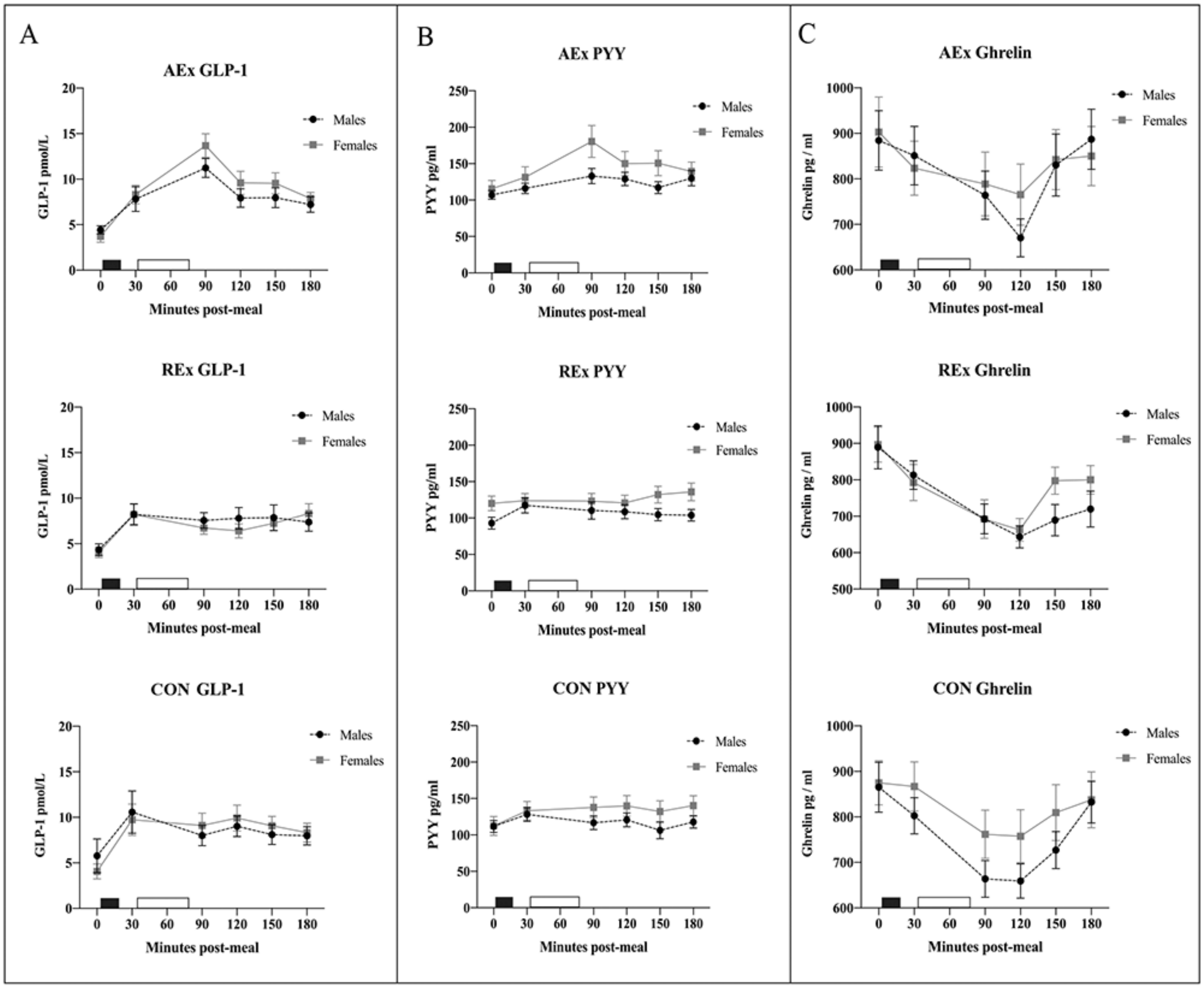

Fig. 2.

Circulating Appetite Hormones in Men and Women. Curves for Circulating gut peptides (A: Glucagon Like Protein-1 (GLP-1) B: Peptide Tyrosine. Tyrosine (PYY) C: Ghrelin) in Men and Women in the AEx, REx, and SED study conditions. Data are presented as mean ± SE; Black rectangle indicates standardized breakfast; Open rectangle indicates study intervention; VAS: visual analogue scale; REx: resistance exercise; CON: sedentary control; AEx: aerobic exercise.

Table 1.

Participant Characteristics

	Total Sample (n = 24)	Women (n = 12)	Men (n = 12)	p-value
Age	34.5 ± 1.5	36.8 ± 2.2	32.3 ± 1.8	0.14
BMI, kg/m^2	28.5 ± 0.9	29.0 ± 1.5	28.1 ± 1.3	0.64
Body Fat % †	35.1± 1.9	30.6± 2.1	40.1± 2.4	0.01 *
TFEI-Dietary Restraint	7.9 ± 0.9	8.2 ± 1.3	7.7 ± 1.4	0.79
TFEI-Dietary Disinhibition	5.9 ± 0.7	5.8 ± 0.9	6.1 ± 1.1	0.82
TFEI- Hedonic Hunger	4.9 ± 0.7	4.0 ± 0.6	5.8 ± 1.3	0.23

Data are presented as mean ± SE. TFEI: three factor eating inventory; REx: resistance exercise; SED: sedentary control; AEx: aerobic exercise; Dietary Restraint Scale: 0-21; Dietary Disinhibition Scale: 0-16; Hedonic Hunger Scale: 0-14

*significant difference between men and women

†Body composition data available for n=19.

Table 2.

Area Under the Curve in Men and Women by Intervention

		Ghrelin (pg/mL x 180 min)		PYY (pg/mL x 180 min)		GLP 1 (pmol/L x 180 min)		VAS Hunger (mm x 180 min)		VAS Satiety (mm x 180 min)		VAS PFC (mm x 180 min)		Relative kcals at *Ad Libitum* Meal (% of total energy needs)	
		Mean ± SEM	**p-value**	**Mean ± SEM**	**p-value**	**Mean ± SEM**	**p-value**	**Mean ± SEM**	**p-value**	**Mean ± SEM**	**p-value**	**Mean ± SEM**	**p-value**	**Mean ± SEM**	**p-value**
AEx	Men	135703.6 ± 6182.6	0.283	21895.91 ± 880.6	0.234	1507.45 ± 91.9	0.308	7815.00 ± 368.3	0.025 *	8167.50 ± 235.9	0.270	9152.50 ± 378.2	0.041 *	44.00 ± 4.62%	0.830
	Women	152136.0 ± 6241.1		25920.00 ± 1663.6		1736.59 ± 71.1		5428.50 ± 440.0		9501.25 ± 627.7		6701.25 ± 525.5		45.33± 4.02%	
REx	Men	12554.505 ± 4064.9	0.281	19498.64 ± 919.0	0.371	1356.18 ± 82.4	0.638	7110.00 ± 548.4	0.427	8946.25 ± 404.2	0.627	8193.75 ± 470.8	0.570	48.33 ± 5.09%	0.792
	Women	136449.00 ± 4136.0		21685.50 ± 1060.0		1266.71 ± 56.7		6086.25 ± 482.9		9538.75 ± 562.4		7435.00 ± 594.1		46.5 ± 4.61%	
CON	Men	127471.40 ± 4410.2	0.085	20584.09 ± 932.3	0.311	1555.62 ± 125.1	0.872	8315.00 ± 429.8	0.021 *	8367.50 ± 332.2	0.403	9062.50 ± 336.4	0.027 *	47.17± 5.09%	0.578
	Women	148240.50 ± 5059.7		23604.00 ± 1405.8		1603.43 ± 93.3		5311.25 ± 543.1		9527.50 ± 704.1		6243.75 ± 582.5		42.83 ± 5.75%	

Data are presented as mean ± SEM; Complete AUC data on circulating Ghrelin and PYY available for n= 21 participants (11 men, 10 women) and on GLP-1 for n=17 (9 men, 8 women) due to missing timepoint data; Appetite ratings were evaluated with 100 mm visual analog scales. REx: resistance exercise; CON: sedentary control; AEx: aerobic exercise; AUC: area under the curve; PFC: prospective food consumption; VAS: visual analog scale

* significant difference between men and women