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Aerobic and Resistance Training Effects on Energy Intake: The STRRIDE AT/RT Study:

Exercise Training Effects on Energy Intake

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Abstract

Purpose—Our study characterizes food and energy intake responses to long-term aerobic (AT) and resistance training (RT) during a controlled 8-month trial.

Methods—In the STRRIDE AT/RT trial, overweight/obese sedentary dyslipidemic men and women were randomized to AT (n = 39), RT (n = 38), or a combined treatment (AT/RT; n = 40) without any advice to change their food intakes. Quantitative food intake assessments (QDI) and food frequency questionnaires (FFQ) were collected at baseline (BEF) and after 8 mo. training (END); body mass (BM) and fat free mass (FFM) were also assessed.

Results—In AT and AT/RT, respectively, meaningful decreases in reported energy intake (REI) (−217 and −202 kcal; $p < 0.001$) and in intakes of fat (−14.9 and −14.9 g; $p < 0.001$, $p = 0.004$), protein (−8.3 and −10.7 g; $p = 0.002$, $p < 0.001$), and carbohydrate (−28.1 and −14.7 g; $p = 0.001$, $p = 0.030$) were found by FFQ. REI relative to FFM decreased ($p < 0.001$ and $p=0.002$) as did intakes of fat (−0.2 and −0.3 g; $p = 0.003$ and $p = 0.014$) and protein (−0.1 and −0.2 g; $p = 0.005$ and $p < 0.001$) in AT and AT/RT and carbohydrate (−0.5 g; $p<0.003$) in AT only. For RT, REI by QDI decreased (−3.0 kcal/kg FFM; $p=0.046$), as did fat intake (−0.2 g; $p = 0.033$). BM decreased in AT (−1.3 kg, $p=0.006$) and AT/RT (−1.5 kg, $p = 0.001$) but was unchanged (0.6 kg, $p = 0.176$) in RT.

Conclusions—Previously sedentary subjects completing 8 months of AT or AT/RT reduced their intakes of kcal and macronutrients and BM. In RT, fat intakes and REI (when expressed per FFM) decreased, BM was unchanged, and FFM increased.

Keywords

aerobic exercise; resistance training; energy intake; body mass; obesity

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INTRODUCTION

The low success rate of lifestyle interventions for obesity presents a significant public health challenge (24). Being overweight (BMI 25.0 – 29.9 kg/m^2; OW) or obese (BMI ≥30 kg/m^2; OB) contributes to an array of serious chronic conditions, including cardiovascular disease, type 2 diabetes, osteoarthritis, asthma, and certain cancers (13). Of those who are OW/OB in the U.S., nearly 74% of women and 60% of men report using one or more weight management strategy (34). Yet, the evidence shows that even if they achieve weight loss by "dieting", most of these individuals will experience weight regain over time (24, 32).

In view of the disappointing track record of diet interventions for OW/OB, exercise is often recommended as the preferred lifestyle intervention to reduce body mass. Exercise can be a facilitator of weight loss by several mechanisms. Exercise directly affects energy balance by increasing total energy expenditure (TEE) and can also have indirect effects via influences on appetite regulation. Recent studies of OW/OB men and women have shown that exercise improves appetite regulation by increasing satiety responses (17, 21). There may also be behavioral benefits from increased physical activity, such as enhanced mood, stress reduction, and improvements in self-rated health (25), providing positive reinforcement for continued exercise adherence. While energy expenditures are generally higher in aerobic exercise than in resistance training(31), there are some reports of weight loss in obese individuals participating in resistance training (26–28).

Despite the many benefits of exercise, the amounts of weight loss observed in controlled studies of exercise-only interventions are often less than would be predicted based on the calculated TEE (5, 7, 12, 30). It has been suggested that this seemingly contradictory observation is due to a compensatory increase in calorie consumption (18) and/or a decrease in spontaneous physical energy expenditure with institution of a dedicated exercise regimen (16). Recently reported exercise trials of six (6, 33) and eight (14) months have not detected changes in non-prescribed physical activity in response to exercise training, prompting speculation that increased energy consumption accounts for the less than predicted weight loss. Yet experimental evidence of increases in food (energy) intake in response to long-term exercise training is lacking, perhaps reflecting the difficulty in studying dietary behaviors over time. Most studies have focused on acute or mid-length, rather than long-term, effects of exercise (22) and used indirect measures of changes in energy intake such as reports of hunger, satiety, or food preference changes. Additionally, the nature of the exercise prescription may affect energy intake in a differential manner depending upon exercise mode. With regards to resistance training, its long-term effects on dietary behaviors have not been extensively studied. However, one study of OW older adults showed no change in calorie intake in a resistance training only group (1). Given the many unanswered questions concerning the influence of both aerobic and resistance exercise training on the food intake behaviors of previously sedentary OW/OB adults, we sought to ascertain the impact of eight months of aerobic and resistance exercise (apart from any diet intervention) on reported intakes of energy and measured body masses.

MATERIALS AND METHODS

In the Studies of a Targeted Risk Reduction Through Defined Exercise (STRRIDE-AT/RT) trial, we collected dietary intake information prior to and at the end of a supervised exercise intervention. Previously sedentary subjects participated in an eight-month program of aerobic training, resistance training, or a combination of both. Food choices were assessed but we were careful to avoid providing any advice to change their meal composition or energy intakes during the intervention period. Body weight was measured but subjects were not instructed to lose, gain, or maintain body mass. The STRRIDE-AT/RT trial thus offered a unique opportunity to observe potential changes in calorie intake that might occur voluntarily in response to aerobic or resistance training, or a combination of both.

Subjects

Subjects were recruited for the STRRIDE-AT/RT study from the surrounding communities of Durham and Greenville, NC, between August 2004 and January 2008. A total of 3,145 potential participants responded to local advertisements and were screened for inclusion via telephone interview with the following exclusion criteria: history of smoking, diabetes, hypertension, and coronary artery disease, currently dieting to lose weight, or taking confounding medications. Eligible participants were sedentary individuals (exercising ≤ 2 times/wk) between the ages of 18 and 70 years, with a body mass index 25–35 kg/m^2, and with mild to moderate dyslipidemia (LDL cholesterol 130–190 mg/dL; or HDL cholesterol ≤ 40 mg/dL for men or ≤ 45 mg/dL for women). The protocol was approved by the IRBs at both institutions, informed consent was obtained prior to baseline testing, and participants were asked to follow their current lifestyle for four months prior to randomization.

Design

Of those who qualified for the study, 196 completed the four-month run-in period and were randomized to one of three exercise training groups: 1) Aerobic Training (AT), (calorically equivalent to ~12 miles/wk at 65–80% VO_2 peak), 2) Resistance Training (RT) (three days/week, three sets/day, 8–12 repetitions/set), 3) AT/RT (linear combination of AT prescription and RT prescription). Randomization was performed with a standard computer-based random number generator using a randomized design, blocked by gender, race, and study site. Aerobic exercise prescriptions were determined at BEG by treadmill cardiopulmonary exercise test (CPET), using a TrueMax 2400 Metabolic Cart (ParvoMedics; Sandy, UT), through measures of expired gas. Absolute peak VO_2 (L/min) was determined by averaging the two highest, consecutive, 15-second readings. Exercise modes included treadmill, elliptical trainers, and cycle ergometers for the aerobic exercises. For subjects randomized into the AT or AT/RT groups, the amount of aerobic activity was ramped over an eight to ten week period to achieve the prescribed number of minutes each week. The RT program for subjects in the RT and AT/RT groups began with one set of each exercise during the first two weeks, followed by two sets during weeks 3 and 4, and reaching the goal of 3 sets at week 5. The RT sessions targeted all major muscle groups, and weight lifted amount was increased by 5 pounds when the subject was able to complete 12 repetitions of all three sets with proper form.

Measurements: Body Mass, Dietary Intakes and Self-Rated Health

Body mass (measured three times over a two-week period and averaged) was assessed before training (BEF) and at the end of training (END). Fat free mass (FFM) was measured (n= 114) using the BOD POD™ air displacement plethysmography method (Life Measurement, Inc., Concord, CA) or by dual energy x-ray absorptiometry (DEXA). Detailed dietary information was recorded at these same time points via 3-day food records and 24-hour diet recall interviews. Following baseline instruction on food characteristic parameters and accurate estimation of portion size, participants were asked to record three days of dietary intakes (two weekdays and one weekend day) at each time point. Dietary records provide a quantitative estimation of foods consumed during the recording period and are often used as a standard for the validation of other diet assessment tools (29). Study participants were also interviewed in person or by telephone and asked to recall all foods/beverages consumed for another unannounced 24-hour time period. Interviewers utilized a modified multiple pass method, consisting of five steps, including an uninterrupted list of the foods consumed, followed by questions to elicit commonly forgotten foods, details about the time and occasion of each eating occasion, a probe to determine the exact amount of foods eaten, and a review of the foods eaten to elicit any forgotten eating occasions or foods. The multiple pass approach limits under-reporting by providing repeated memory cues and opportunities to recall and report food intake and has been established to be both reliable and valid when compared with foods actually eaten (8, 9). Dietary intakes recorded from the 3-day records and 24-hour recalls were analyzed for calorie and macronutrient content using Food Processor SQL Nutrition Analysis Software (Version 9.6, 2005, ESHA Research, Salem, OR), which provides access to information on over 15,000 food items with data for 105 nutrient components. Complete information was available at BEF and END for 117 of the 144 STRRIDE-AT/RT completers. We found no statistical differences between the daily energy intakes derived from three-day records and the intakes in 24-hr recalls, so information from these two sources was averaged together to give a single quantitative daily dietary intake (QDI).

Information about food intake was also collected at the BEF and END time-points using a food frequency questionnaire, the Block 1998 Revision of the Health Habits and History Questionnaire (Block Dietary Data Systems, Berkeley, CA; FFQ). This FFQ collects information on the frequency of consumption of many types of foods and is thus useful as a semi-quantitative measure of food group intake patterns. The FFQ we used has been very widely used and has been well validated for use in populations similar to the subjects in STRRIDE AT/RT. (3, 20) Completed FFQs were analyzed by Block Dietary Data Systems for energy and macronutrient content. Complete FFQ information was available at BEF and END for 73 of the 144 STRRIDE completers. Reported Energy Intakes (REIs) were calculated from both the QDI and FFQ results as absolute amounts, relative to body mass, and relative to FFM. Macronutrient intakes were calculated as absolute amounts and relative to FFM. The FFQ also included a question about self-rated health. At BEF and END subjects were asked to complete the statement “My health is ……” with the potential choices of “Excellent (1), Very Good (2), Good (3), Fair (4), or Poor (5).” The validity of using a single-item subjective measure of overall health is well established (10).

Records of all aerobic exercise sessions were kept through direct supervision by staff and use of a monitor that produced downloadable heart rate and exercise duration data (Polar Electro, Inc; Woodbury, NY). Adherence percentages were calculated weekly and were equal to the number of minutes completed within the prescribed heart rate range divided by the number of total minutes prescribed. All resistance training sessions were verified by direct supervision and/or use of the FitLinxx Strength Training Partner™, (FitLinxx; Norwalk, CT). Throughout each workout, the “training partner” captured and stored information including the amount of weight lifted, verified by infrared laser, and the number of repetitions and sets completed within the pre-programmed speed and range of motion limits. Exercise adherence represented the percent of prescribed exercise sessions completed each week.

Statistical Analysis

Descriptive statistics were derived and are presented as medians, along with 25th and 75th percentiles. For all the before-after measures, we had data at baseline (BEF) and data at follow-up (END), and we also calculated a change score (Delta). The sequence of statistical analyses was as follows: (1) We described the distribution of the measure at baseline (Table 1); (2) We compared the 3 treatment groups at baseline (Table 1); (3) we calculated Deltas for the overall group (n = 117), and compared the mean/median Deltas to 0 (Table 2); (4) we calculated Deltas by treatment group, and compared these mean/median Deltas to 0 (Tables 3 and 4): and (5) secondarily, we correlated the Deltas against other measures, such as exercise adherence (in the text). Analyses 1–4 were accomplished using the Wilcoxon test (e.g., either the 1 sample pair or unpaired, as appropriate), or its extension. Analysis 5 used the Spearman (non-parametric) correlation coefficient. A p-value of < 0.05 was considered to be statistically significant. Adjustments for multiple comparisons were not taken into account.

RESULTS

Baseline characteristics of the study participants (n = 117; BMI = 30.3 kg/m^2; age = 49.0 yr; baseline energy intake = 1990 kcal) are listed for the entire cohort and by treatment group in Table 1. Individuals in the three treatment groups (AT, RT, or AT/RT) did not differ with respect to age, gender, BMI, kilocalorie intake, or kilocalorie intake relative to body mass at baseline. Likewise, the subgroup of subjects (n = 73) who completed the FFQ, did not differ from the remainder of the total cohort (n = 44) with respect to any of these parameters.

Based on monitored exercise compliance during the trial, mean adherence to prescribed exercise treatment was 90.1, 82.9, and 83.3/82.0% for the AT, RT, and AT/RT groups, respectively. The aerobic exercise adherence between AT and AT/RT did not differ (p = 0.157). Likewise, the resistance training adherence did not differ between the RT and AT/RT (p = 0.956). Small but meaningful improvements in self-rated health scores were recorded between BEF and END for the total group (−0.33; p < 0.001), as well as for the AT group (−0.54; p < 0.001).

As shown for the total group in Table 2, there was no increase in reported energy intake (REI). In fact, REI decreased between baseline and END, as determined in both the FFQ (p < 0.001) and QDI (p = 0.003) assessments. Corresponding with the reduced REI, there was a decrease in the absolute intakes of fat (QDI p = 0.026; FFQ p < 0.001), protein (QDI p = 0.131; FFQ p < 0.001), and carbohydrate (QDI p = 0.002; FFQ p < 0.001); however, the proportions of calories provided by each of these macronutrients were unchanged.

In comparison to BEF, median body masses at END were decreased in the AT (−1.3 kg, CI = −3.4, 0.6; p < 0.006) and AT/RT (−1.5 kg, CI = −4.5, 0.5; p < 0.001) groups, but were unchanged (0.6 kg, CI = −1.0, 1.9; p = 0.176) in the RT group (Table 3). Looking between groups, the change in body mass between BEF and END differed between RT and AT (p = 0.020) and between RT and AT/RT (p < 0.001). With regards to body composition at END versus BEF (Table 5), fat mass (in kg and as a percent) decreased (−2.3 kg and −1.6%; p <0.001) in the AT/RT group and FFM increased in the RT group (+1.0 kg; p< 0.042) and tended to increase (+0.6 kg; p<0.097) in AT/RT.

For the within treatment group analyses of calorie and nutrient intake in absolute terms (Tables 3 and 4), the same general pattern was reflected in the results for the two groups that included an aerobic exercise component. Based on the FFQ results, there were meaningful decreases in absolute intakes of calories (−217 and −202 kcal; p<0.001) and in intakes of protein (−8.3 and −10.7 g; p = 0.002, p < 0.001), carbohydrate (−28.1 and −14.7 g; p = 0.001, p = 0.030), and fat (−14.9 and −14.9 g; p < 0.001, p = 0.004) for the AT and AT/RT groups, respectively. While these same trends were seen in the QDI results, for the most part the changes were non-significant; however, the QDI showed a decrease (p=0.050) in absolute fat intakes for RT. When we expressed calorie intakes relative to body mass, we found the same results in terms of significance, namely that calorie intakes decreased in the AT (p = 0.001) and AT/RT (p = 0.007) groups (FFQ findings) but were unchanged in RT (p = 0.938). When we expressed the calorie intakes per FFM, as shown in Table 3, again the FFQ data showed a decrease in REI in the AT (p < 0.001) and AT/RT (p = 0.002). While in the RT there was no change in REI by FFQ (p = 0.962), the QDI results showed a decrease (−3.0 kcal/kg FFM; p=0.046). As also shown in Table 4 and in agreement with the findings on absolute amounts, when expressed per FFM, the FFQ showed that intakes of fat (p = 0.003 and p = 0.014) and protein (p = 0.005 and p < 0.001) decreased in the AT and AT/RT, respectively. Carbohydrate in g/kg FFM decreased ($p<0.003$) in AT only. When expressed relative to FFM, the only change in the intakes of macronutrients in RT was a decrease in fat intake by QDI ($p<0.033$).

Spearman correlation analyses showed no association between changes in REI and changes in body weight in the aerobic exercise groups (AT and AT/RT). Likewise, change in REI was not related to level of exercise adherence. In the RT group, however, change in REI was directly correlated with change in body mass (correlation coefficient 0.36, $p = 0.03$) but was not related to change in FFM (correlation coefficient 0.16, $p = 0.267$).

DISCUSSION

The STRRIDE-AT/RT trial presented the unique opportunity to carefully assess changes in reported energy and macronutrient intakes in previously sedentary individuals completing a long term (eight-month) exercise program with no concomitant dietary intervention. This target population of overweight/obese and dyslipidemic adults, in particular, is in need of interventions that successfully promote favorable changes in body composition (i.e., loss of fat, retention of FFM) and the exercise prescriptions studied in STRRIDE AT/RT were selected to be the most appropriate for this group. Additionally, the head to head comparison of AT to RT exercise yields important new information about the impact of these modalities on calorie intake.

At the end of the trial, participants in both exercise interventions that included an aerobic component (the AT and AT/RT groups) reported lower calorie intakes in absolute amounts and relative to body mass. When REI was expressed relative to FFM, all three treatment groups had a reduced REI by one of the two modes of assessment (QDI or FFQ). Thus, our findings do not support an energy intake increase in response to exercise, although we emphasize that this may apply only within the realm of the exercise prescriptions and the specific population we studied. This finding is in agreement with the available literature, which has failed to directly demonstrate increased calorie intake in response to increases in physical activity level. (19) In fact, we are not aware of any long term study that has shown increased food intake in response to exercise in previously sedentary subjects. Moreover, recent studies of appetite-related gut hormones have shown improved appetite regulation in response to chronic exercise, providing mechanistic support for our findings. (21) Clearly, the relationship of appetite and satiety to changes in exercise activity level is complex and in need of further study. While mechanistic findings support a blunting of appetite by aerobic exercise (4), the long term effects and relations of changes in food intake to shifts in gut hormones following exercise have not been fully delineated. In a medium-term (twelve-week) supervised exercise study of appetite-related hormones, Martins *et al.* (21) observed an increased drive to eat in the fasting state in 22 previously sedentary overweight/obese adults but this was balanced by improved appetite control and improved satiety responses to a meal. Further study in long-term trials is needed to help clarify these mechanisms and relate them to body mass and body composition responses to both aerobic and resistance training.

Recognizing the suggestion that exercise-induced body mass changes might differ depending on whether an individual is a “responder” versus a “non-responder” to exercise (18), we sought to determine whether energy intake changes for individual STRRIDE participants might reflect the actual level of physical activity they had attained during the study. We were able to examine this by looking at exercise adherence data for all aerobic exercisers, since the AT and AT/RT groups had identical aerobic exercise prescriptions. However, we did not find that changes in energy intake in the STRRIDE-AT/RT subjects were related to their levels of exercise adherence. The correlation of change in body weight to aerobic exercise adherence was −0.198 ($p = 0.227$) and −0.188 ($p = 0.245$) in the AT and AT/RT groups, respectively. The correlation of change in body weight to resistance training exercise adherence was −0.109 ($p = 0.516$) and 0.067 ($p = 0.681$) in the RT and AT/RT groups, respectively.

Total body mass was unchanged in the RT group, although they increased FFM (Table 5). We found the REI in this group was either unchanged (in absolute amounts or relative to body mass) or decreased relative to FFM (by 3 kcal/g FFM per QDI findings; $p=0.046$). Thus, our results do not support an increase in energy intake in response to RT. In addition, the increase in FFM in the RT subjects could make them more resistant to developing obesity in the future.

With respect to meal composition, we observed decreases in absolute intakes of macronutrients (protein, carbohydrate and fat) in the AT and AT/RT groups that reflected an overall lowered food intake and paralleled their reductions in energy intake; but, there were very few changes in the macronutrient distribution for either the AT or AT/RT groups. The available literature on diet composition responses to long-term exercise in adults is sparse (2); the lack of any clear trend is loosely in agreement with our observation that the proportions of energy-yielding macronutrients were largely unchanged. One medium-length (twelve-week) study identified individual differences, such that some subjects (but not others) showed an immediate post-exercise preference for sweet, high-fat foods, but dietary changes were not assessed in those subjects (11).

It should be emphasized that our findings regarding the influence of exercise training on REI may only apply to the levels of exercise achieved in this study, which are categorized within the range of moderate intensity aerobic exercise (65–80% VO_2 peak). Based on previous research, it is possible that higher levels of exercise intensity produce an increase in energy intake (23). We also acknowledge the limitation that our study depends upon self-reported energy intakes rather than a more precise measure. It is possible that the mere process of reporting food intakes caused some subjects to change their intakes and/or their reports. Our findings could be affected by the oft-cited problem of total and/or selective under-reporting (15). However, the fact that we found very similar post-exercise results using two relatively different dietary assessment approaches lends strength to our conclusions. The QDI assessment collects real-time quantitative information by interview or in writing, while the FFQ provides a semi-quantitative assessment of types and amounts of foods consumed over a period of months. Both measures indicated a reduction in calorie intake between BEF and END. Adding additional confidence is the fact that these same results were found when REI was expressed relative to body weight or relative to FFM. It should also be noted that, since this was not a diet or weight loss trial, participants knew they were not being “judged” for their dietary choices and thus had no reason to hesitate about reporting them. And, even if underreporting occurred, there is no reason to think it would worsen over time; if anything, one would expect reporting to be more complete over time as subjects become more familiar with the assessment methods and offer more details about their food intakes.

In summary, we observed carefully supervised, long term aerobic and resistance training exercise programs in a population of overweight/obese, previously sedentary individuals and examined REIs in absolute and relative amounts over time. We found that energy intakes did not increase in response to aerobic or resistance exercise; in fact, energy intakes decreased slightly between the beginning and end of training. These results counter the claim that sedentary individuals who initiate a long term exercise program increase their energy intakes in a compensatory fashion.

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Table 1

Baseline Subject Profile for the Total Group and by Treatment Group

	Total	AT	RT	AT/RT
n	**117**	**39**	**38**	**40**
Women, n (%)	**62 (53)**	**20 (51.3)**	**20 (52.6)**	**22 (55.0)**
Race				
Caucasian/Other (%)	**102/15 (87.2)**	**35/4 (89.7)**	**33/5 (86.8)**	**34/6 (85.0)**
Age (yrs)†	**49.0** (42.0, 57.0)	**53.0** (45.0, 57.0)	**48.5** (41.8, 59.2)	**47.0** (41.2, 54.5)
BMI (kg/m^2)†	**30.3** (27.9, 33.0)	**30.1** (27.8, 32.6)	**30.4** (28.6, 33.4)	**30.2** (27.6, 33.4)
Energy Intake (kcal)†	**1990** (1692, 2348)	**1962** (1571, 2397)	**1980** (1690, 2385)	**1994** (1867, 2343)
Kcal/kg Body Mass†	**22.6** (19.2, 26.9)	**23.1** (18.8, 25.6)	**21.9** (19.4, 27.6)	**22.3** (19.4, 27.1)

Abbreviations: AT = Aerobic training; RT = Resistance training; AT/RT = Combination of AT and RT

†Median (25th, 75th quartile)

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Table 2

Intakes of Energy and Macronutrients Assessed by Two Methods For Total Group[*†]

	BEF	END	Change	P
Reported Energy Intake (kcal)				
QDI[†]	1990 (1693, 2348)	1819 (1561, 2267)	−127 (−388, 158)	0.003
FFQ[†]	1761 (1442, 2164)	1506 (1206, 2043)	−202(−451, −5)	<0.001
Total Fat (g)				
QDI	78.2 (62.6, 96.7)	71.1 (58.4, 90.7)	−4.5 (−21.4, 10.6)	0.026
FFQ	77.6 (60, 102.8)	67.0 (47.6, 94.5)	−12.1 (−26.2, 4.2)	<0.001
Fat (% kcal)				
QDI	35.5 (31.0, 39.1)	35.3 (31.7, 39.0)	−0.1 (−4.4, 4.0)	0.851
FFQ	40.8 (38.0, 44.8)	40.5 (36.5, 43.2)	−0.01 (−4.4, 3.1)	0.378
Total Protein (g)				
QDI	80.8 (67.7, 94.7)	75.3 (64.2, 92.3)	−0.4 (−21.2, 10.8)	0.131
FFQ	62.6 (49.0, 80.6)	53.4 (45.2, 72.8)	−7.6 (−20.3, 1.9)	<0.001
Protein (% kcal)				
QDI	15.7 (14.3, 18.1)	16.6 (14.5, 18.5	0.9 (−1.8, 2.9)	0.133
FFQ	14.6 (13.0, 16.5)	15.0 (13.3, 17.0)	0.2 (−1.5, 1.4)	0.752
Carbohydrate (g)				
QDI	239.0 (197.0, 287.8)	216.3 (183.2, 273.4)	−21.1 (−53.6, 19.3)	0.002
FFQ	196.0 (155.8, 246.0)	172.2 (138.2, 229.4)	−17.8 (−45.2, 4.0)	<0.001
Carbohydrate (% kcal)				
QDI	48.7 (44.1, 52.2)	48.2 (43.2, 53.3)	−0.9 (−4.8, 4.4)	0.660
FFQ	45.9 (41.6, 49.6)	47.2 (43.2, 50.4)	0.3 (−3.4, 5.3)	0.491

Abbreviations: AT: Aerobic training; RT: Resistance training; AT/RT: Combination of AT and RT; BEF: Before Training; END: End of Training; QDI: Average of data collected using 3-day records and 24 hr diet recalls; FFQ: Data collected by food frequency questionnaire.

[*]Comparisons using Wilcoxon signed Rank Test.

[†]Data are median (25th, 75th percentile) for *n=117* QDI and *n=73* FFQ.

Table 3

Absolute and Relative Energy Intakes and Body Mass Changes by Treatment Group[*,†]

	AT			RT			AT/RT		
	BEF	**Change**	**P**	**BEF**	**Change**	**P**	**BEF**	**Change**	**P**
Reported Energy Intake (kcal)[¥]									
QDI[†]	**1962** (1571, 2397)	**−117** (−206, 153)	**0.145**	**1980** (1690, 2385)	**−179** (−525, 194)	**0.073**	**1994** (1867, 2343)	**−185** (−451, 125)	**0.073**
FFQ[†]	**1864** (1503, 2483)	**−217** (−562, −80)	**<0.001**	**1541** (1251, 1933)	**−62** (−337, 431)	**0.913**	**2003** (1481, 2244)	**−202** (−408, −95)	**<0.001**
Body Mass[€]									
	88.0 (81.3, 94.6)	**−1.3** (−3.4, 0.6)	**0.006**	**91.2** (77.3, 101.8)	**0.6** (−1.0,1.9)	**0.176**	**90.9** (81.5, 99.5)	**−1.5** (−4.5, 0.5)	**0.001**
Reported Energy Intake (kcal/kg lean body mass)									
QDI(n=114)	**37.5** (33.4, 42.8)	**−1.9** (−4.3, 4.2)	**0.480**	**38.5** (28.5, 42.9)	**−3.0** (−12.1, 3.6)	**0.046**	**38.8** (31.5, 44.4)	**−2.5** (−8.8, 3.6)	**0.063**
FFQ(n=72)	**32.8** (26.6, 43.3)	**−4.1** (−10.5, −1.1)	**0.001**	**28.2** (21.1, 36.9)	**−1.26** (−5.74, 5.46)	**0.962**	**33.7** (23.1, 45.7)	**−3.2** (−7.3, −0.5)	**0.002**

Abbreviations: AT: Aerobic training; RT: Resistance training; AT/RT: Combination of AT and RT; BEF: Before Training;

[*] Comparisons using Wilcoxon signed Rank Test.

[†] Data are median (25th, 75th percentile) for (*n=117)* QDI and (*n=73)* FFQ, unless otherwise noted.

[¥] RT differed from AT (p=0.012) and AT/RT (p=0.0354) using unpaired t test.

[€] RT differed from AT (p=0.020) and AT/RT (p < 0.001) using unpaired t test.

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Table 4

Macronutrient Intakes and Changes By Treatment Group*

	AT			RT			AT/RT		
	BEF	Change	P	BEF	Change	P	BEF	Change	P
Total Fat (g)									
QDI†	**73.5** (62.6, 93.5)	**2.1** (−13.8, 12.4)	**0.602**	**78.6** (59.5, 106.7)	**−10.0** (−28.5, 11.5)	**0.050**	**78.8** (63.9, 93.3)	**−8.8** (−28.0, 5.0)	**0.044**
FFQ†	**82.7** (65.5, 111.2)	**−14.9** (−37.4, 2.1)	**<0.001**	**69.1** (51.5, 87.8)	**−3.8** (−16.7,26.1)	**0.766**	**78.9** (61.3, 107.3)	**−14.9** (−26.1, 0.1)	**0.004**
Relative Fat intake (g/kg lean body mass)									
QDI	**1.5** (1.2, 1.7)	**0.1** (−0.1, 0.3)	**0.371**	**1.5** (1.0, 2.0)	**−0.2** (−0.5, 0.2)	**0.033**	**1.4** (1.1, 1.8)	**−0.2** (−0.5, 0.1)	**0.023**
FFQ	**1.6** (1.2, 2.0)	**−0.2** (−0.6, 0.1)	**0.003**	**1.2** (1.0, 1.6)	**−0.1** (−0.3, 0.3)	**0.701**	**1.5** (0.9, 1.9)	**−0.3** (−0.4, 0.0)	**0.014**
Fat (% kcal)									
QDI	**35.5** (30.5, 38.9)	**1.2** (−0.8, 6.7)	**0.02**	**36.2** (32.9, 40.7)	**−0.1** (−6.6, 4.9)	**0.428**	**35.1** (30.8, 38.9)	**−1.3** (−4.6, 1.9)	**0.039**
FFQ	**42.9** (38.2, 45.5)	**−2.5** (−5.6, 2.8)	**0.092**	**40.7** (38.9, 44.2)	**0.54** (−3.8, 2.8)	**0.988**	**40.0** (36.2, 43.2)	**0.9** (−4.9, 6.3)	**0.616**
Total Protein (g)									
QDI	**78.6** (63.8, 93.4)	**−2.0** (−15.4, 9.7)	**0.379**	**81.1** (67.3, 96.6)	**−5.7** (−30.5, 13.2)	**0.091**	**80.9** (69.8, 94.6)	**1.2** (−19.4,	**1.00**
FFQ	**65** (50.2, 80.3)	**−8.3** (−23.0, −2.0)	**0.002**	**50.6** (42.9, 69.9)	**0.95** (−10.8,13.8)	**0.950**	**75.1** (54.6, 95.4)	**−10.7** (−20.1, −4.6)	**<0.001**
Relative Pro intake (g/kg lean body mass)									
QDI	**1.4** (1.2, 1.6)	**−0.02** (−0.3, 0.2)	**0.526**	**1.5** (1.1,1.8)	**−0.3** (−0.5, 0.3)	**0.076**	**1.5** (1.3, 1.7)	**0.0** (−0.4, 0.3)	**0.816**
FFQ	**1.1** (1.0, 1.7)	**−0.1** (−0.4, −0.0)	**0.005**	**1.0** (0.7, 1.3)	**−0.0** (−0.2, 0.3)	**0.813**	**1.3** (0.9, 1.8)	**−0.2** (−0.3, 0.0)	**<0.001**
Protein (% kcal)									
QDI	**15.7** (13.4, 18.3)	**1.2** (−1.6, 2.3)	**0.315**	**16.5** (14.8, 18.9)	**0.2** (−3.6, 2.6)	**0.771**	**15.6** (14.5, 17.7)	**1.2** (−1.3, 3.6)	**0.048**
FFQ	**14.5** (12.9, 15.7)	**−0.1** (−2.8, 1.8)	**0.894**	**14.1** (12.2, 16.1)	**0.5** (−1.2,2.5)	**0.294**	**15.9** (13.7, 17.2)	**−0.2** (−1.6, 1.2)	**0.680**
Carbohydrate (g)									
QDI	**239.8** (185.4, 299.0)	**−24.4** (−57.3, 8.0)	**0.012**	**230.1** (191.1, 272.5)	**−8.8** (−70.1, 22.6)	**0.231**	**242.8** (215.2, 298.1)	**−22** (−48.5, 18.6)	**0.085**
FFQ	**208.1** (159.3, 267.1)	**−28.1** (−51.0, −8.2)	**0.001**	**178.4** (144.8, 226.2)	**−8.3** (−40.1, 33.0)	**0.695**	**199.1** (168.3, 243.3)	**−14.7** (−48.0, 13.4)	**0.030**
Relative CHO intake (g/kg lean body mass)									
QDI	**4.4** (3.8, 5.2)	**−0.4** (−0.9, 0.3)	**0.051**	**4.3** (3.5, 5.0)	**−0.3** (−1.1, −0.3)	**0.123**	**4.8** (3.8, 5.3)	**−0.5** (−0.9, −0.4)	**0.109**
FFQ	**3.7** (2.8, 5.1)	**−0.5** (−0.8, −0.2)	**0.003**	**3.1** (2.5, 4.0)	**−0.2** (−0.7, 0.6)	**0.883**	**4.0** (2.9, 5.0)	**−0.2** (−0.8, 0.1)	**0.053**
Carbohydrate (% kcal)									
QDI	**48.9** (44.8, 52.5)	**−2.3** (−7.4, 0.6)	**0.044**	**47.7** (43.4, 50.1)	**0.2** (−5.3, 9.9)	**0.395**	**48.8** (44.4, 54.2)	**0.7** (−3.3, 4.3)	**0.552**
FFQ	**45.2** (41.3, 49.7)	**0.9** (−2.8, 8.1)	**0.208**	**48.0** (41.1, 50.0)	**0.1** (−5.4,2.1)	**0.718**	**45.7** (43.7, 49.0)	**0.3** (−1.8, 6.0)	**0.930**

Abbreviations: AT: Aerobic training; RT: Resistance training; AT/RT: Combination of AT and RT; BEF: Before Training; QDI: Average of data collected using 3-day records and 24 hr diet recalls; FFQ: Data collected by food frequency questionnaire.

*Comparisons using Wilcoxon signed Rank Test.

†Data are median (25^{th}, 75^{th} percentile) for (*n=117)* QDI and (*n=73)* FFQ.

Table 5

Baseline Body Composition and Changes By Group*

	AT			RT			AT/RT	
BEF	**Change**	**P**	**BEF**	**Change**	**P**	**BEF**	**Change**	**P**
LBM (kg)								
52.8 (46.3, 60.9)	**−0.2** (−1.5, 0.5)	**0.139**	**55.5** (45.8, 70.1)	**1.0** (−0.1, 2.3)	**0.042**	**56.4** (44.8, 65.7)	**0.6** (−0.6, 1.7)	**0.097**
FM (kg)								
32.5 (27.6, 39.2)	**−1.0** (−3.0, 1.4)	**0.193**	**35.1** (25.6, 39.4)	**−0.3** (−1.7, 1.5)	**0.604**	**33.6** (25.8, 40.6)	**−2.3** (−4.8, 0.2)	**<0.001**
FM (%)								
37.9 (32.9, 45.0)	**−0.5** (−1.8, 0.8)	**0.283**	**36.8** (29.9, 43.5)	**−0.6** (−1.8, 0.8)	**0.175**	**37.7** (31.7, 43.7)	**−1.6** (−3.8, 0.0)	**<0.001**

Abbreviations: AT: Aerobic training; RT: Resistance training; AT/RT:Combination of AT and RT; BEF: Before Training;

*Comparisons using Wilcoxon signed Rank Test.

† Data are median (25^{th}, 75^{th} percentile) for (*n=114; AT=38, RT-37, ATRT=39).*