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Impact of Exercise Modes on Appetite Markers

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ABSTRACT This study investigates the effects of different acute exercise modes on appetite marker ratings. Twelve healthy male subjects participated voluntarily in the study and written informed consent was obtained from all subjects before participation. The subjects underwent four, 120 minute trials (exercise and control) in a randomized crossover design. These included three exercises and one control. In the exercise trials, the subjects performed three different exercise protocols (60 minutes exercise and 60 minutes recovery). In the control trial, subjects rested for 2 hours. The ratings of subjective feelings of appetite markers were reported on 100 mm visual analogue scales (VAS) at baseline and at 20, 40, 60,80, 90, 120 minutes after baseline. The visual analogue scales (VAS) were used to measure the following appetite markers: (i) hunger, (ii) fullness, (iii) desire to eat, and (iv) prospective food consumption. Repeated-measures, and two-factor ANOVA were used to examine differences between the four trials over time to note appetite marker changes. Between-trial differences at each time point were examined using a one-way ANOVA and the Bonferroni post hoc tests when significant interactions were found. The two-way ANOVAs revealed significant ($P<0.05$) trial *x* time effects ($P<0.05$) and time ($P<0.05$) effects in all appetite markers except hunger. The exercise modes are not different from control ($P>0.05$) in any of the appetite markers except for the feeling of satiety, and the differences between exercise modes are that, combined exercises decrease the feeling of satiety more than combined exercises, and caused desire to eat and prospective food consumption more than resistance exercises ($P<0.05$). In conclusion, this finding lends support for a role of exercise in weight management.

INTRODUCTION

Overweight and obesity are defined as abnormal or excessive fat accumulation that present a risk to health. Overweight and obesity are major risk factors for a number of chronic diseases, including diabetes, cardiovascular diseases and cancer (Deighton et al. 2014). Once considered a problem only in high-income countries, overweight and obesity are now dramatically on the rise in low- and middle-income countries, particularly in urban settings (Przybylowicz et al. 2014).

Given the current levels of obesity there is a need to better understand processes of appetite control and energy balance. The regulation of appetite and energy intake is influenced by numerous hormonal and neural signals, including feedback from changes in diet and exercise. The relationship between exercise and appetite regulation has important implications regarding the role of exercise in weight management (King et al. 2015). Exercise can suppress subjective appetite ratings, subsequent energy intake, and alter appetite-regulating hormones for a period of time post-exercise (Howe et al. 2014). Diet and exercise are two lifestyle behaviors that can influence appetite and energy intake, thus, ultimately altering energy balance.

Many researchers have studied the effect of exercise on appetite markers. Most of these researches on acute exercises studied the effects of endurance and sprint-interval exercises (Thivel et al. 2012; Deighton et al. 2013; Hagobian et al. 2013; Williams et al. 2013; Alkahtani et

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al. 2014; Desgorces et al. 2014; Martins et al. 2014). Today, endurance, resistance and combined exercises are frequently used in weight-control exercise programs (Haskell et al. 2007; Nelson et al. 2007; Donnelly et al. 2009, Garber et al. 2011). Therefore, it is of great importance that the effects of resistance and combined exercises are known, besides the effects of aerobic exercise on appetite markers.

There are few researches that examine the effect of resistance exercises on appetite, and most of these are chronic studies (Guelfi et al. 2013). To the best of the researchers' knowledge, there are only two researches on the effect of acute resistance exercise on appetite and the findings of which are contradictory (Broom et al. 2009; Laan et al. 2010; Ozen et al. 2014).

However, various factors such as exercise mode, intensity and individual characteristics including training status or hedonic responses to exercise may moderate the relationship between exercise and appetite (Horner et al. 2014). Thus, more research is needed to understand the impact of various modes and intensities of exercise and fitness levels on appetite in different populations. Accordingly, the purpose of the study is to examine the effect of 60-minute acute resistance, treadmill and combined exercise on appetite markers in healty men.

METHODOLOGY

Study Design

Ratings of subjective feelings of hunger, in response to rest and exercise trials (endurance, resistance, combine exercise) were investigated using a randomized crossover design. The subjects acted as their own controls and were assigned to the two experimental conditions (resting and exercises), one week apart, in a counterbalanced order.

Subjects

Twelve healthy male subjects participated voluntarily in the study and written informed consent was obtained from all subjects before participation. The subjects were excluded from participation in the study if they had a history of a chronic disease (for example, cancer, heart disease, diabetes), uncontrolled hypertension or taking blood pressure medication, any condition that would alter one's metabolism (for example, thyroid disease) or ability to exercise (for example, orthopedic limitations), diagnosed psychological disorders (for example, depression), recent weight loss of more than 5 kg or low levels of sleep (<6 h/night). The ethical board of the Abant Izzet Baysal University School of Medicine Clinical Laboratory Research, Bolu, Turkey approved the study and it was performed in accordance with the principles of the Declaration of Helsinki. The characteristics of the subjects at baseline are shown in Table 1.

Table 1: Descriptive characteristics of subjects at baseline (mean±sd)

Characteristics	*Mean±sd*
Age (yrs)	19.83± 1.52
Height (cm)	173.16± 9.30
Weight (kg)	67.62± 4.86
BMI (kg/m^2)	22.69± 2.71
Body fat (%)	11.62± 4.57

Preliminary Test

Anthropometric Measurements

Height was measured to the nearest 0.1 cm using a Holtain fixed wall stadiometer. Body mass was measured to the nearest 0.01 kg using a beam balance. BMI was calculated as weight in kilograms divided by the square of height in meters. Percentage body fat was measured with the Tanita Body Composition Analyzer.All body weight measurements were obtained with subjects wearingshorts and a T-shirt, without shoes.

10-Repetition Maximum Strength Test

A 10-repetition maximum test was completed for each of the 7 resistance exercises employed in the study. The order in which each exercise was performed was leg press, leg curl, chest press, lat pull down, shoulder press, biceps curl, sit–up. On a separate visit, subjects undertook a 60-minute familiarization session wherein they completed a full weight-lifting session: three sets of 10 repetitions of 7 different weight-lifting exercises at eighty percent of 10 repetitions maximum.

Maximal Aerobic Capacity Measurement

Maximal oxygen uptake test was performed one weekbefore the main trials. The subject's VO_2

max was assessed during a graded exercise treadmill (HP Cosmos MercuryMed 4.0) test using the standard Bruce protocol (Bruce et al. 1973) in the morning hours. The test was terminated when subjects stated they could no longer continue with the maximum workload. At the terminal workload, all subjects had to meet at least two of the following criteria for a valid test: (1) a final respiratory exchange ratio (RER) > 1.0, (2) O_2 consumption increased by < 2 ml·kg-1 with an increase in exercise intensity, (3) attainment of >85 percent of age-predicted maximal heart rate.

Respiratory gases werecollected and analyzed throughout the entire exercise session with the use of a computer controlled breath-by-breath analyzer Cortex II Metalyser (Cortex Biophysik, Leipzig, Germany). The highest achieved value for oxygen consumption was considered the subject's VO_2max. The heart rate (HR) was measured continuously during the test using a commercially available HR monitor (Polar S725X, Polar Electro, Finland).

Main Trials

Participants were given at least one week to recover from the preliminary exercise tests before performing four main trials (3 exercise and control) in a random, crossover design with an interval of at least one week between trials.

Exercises and Control Trials

Subjects undertook four, 2-hour trials (3 exercises and 1 control) in a randomized crossover design. In the exercise trials, subjects performed three different exercise protocols (60 minutes exercise and 60 minutes recovery). In the control trial, subjects rested for 2 hours.

Exercise Trials

Resistance Exercise: In the resistance exercise trial, subjects performed three sets of 10 repetitions for each exercise (leg press, leg curl, chest press, lat pull down, shoulder press, biceps curl, sit-up) at eighty percent of 10RM. A 60-second rest interval between exercises and a 2-minute rest interval between sets were provided.

Treadmill Exercise: In the treadmill trial, subjects ran for 60 minutes at seventy percent of maximal oxygen uptake followed by a 60-minute rest period.

Combined Exercise: In the combined exercise trial,subjects ran for 40 minutes at seventy percent of maximal oxygen uptake and 20 minutes of resistance exercise followed by a 60-minute rest period.

Appetite: The ratings of subjective feelings of appetite markers in response to rest and exercise forms were investigated using a randomized crossover design. Ratings of subjective feelings of appetite markers were reported on 100 mm visual analogue scales (VAS) at baseline and at 20, 40, 60, 80, 100 and 120 minutes after baseline. Visual analogue scales (VAS) were used to measure the following appetite markers:

(i) Hunger,
(ii) Fullness,
(iii) Desire to Eat
(iv) Prospective Food Consumption.

Specifically, participants were asked to provide subjective ratings of their current state for the following appetite markers:

(i) Hunger – 'How hungry do you feel at this moment?'
(ii) Fullness – 'How full does your stomach feel at this moment?'
(iii) Desire to Eat – 'How strong is your desire to eat at this moment?'
(iv) Prospective Food Consumption – 'How much food do you think you could eat at this moment?'

Statistical Analysis

Paired sample t-tests were used to assess differences between baseline values for each of these variables on the control and exercises trials. Repeated measures and two-factor ANOVA tests were used to examine differences between the two trials over time for hunger change. Between-trial differences at each time point were examinedusing one-way ANOVA and Bonferroni post hoc tests when significant interactions werefound. Mauchley's test was conducted to examine sphericity for the repeated measures analyses. If the assumption of sphericity was violated, the Greenhouse-Geisser adjustment was used to protect against type I error. Statistical analysis was carried out using SPSS version 17.0 (SPSS, Inc., Chicago, IL, USA). Statistical significance was accepted at the five percent level.

RESULTS

Hunger

Baseline fasting hunger did not differ significantly (Repeated Measures ANOVA, P=0.309) between trials. Two-factor ANOVA revealed a main effect of time (P =0.000) for hunger, but there was no main effect of trial (P= 0.410) and no interaction (P= 0.254) effect (Table 2). These results indicate that hunger changed significantly during the trials but were not influenced by modes of exercise.

Table 2: Hunger values over 120 min during the exercise and control trials. Two-factor ANOVA revealed a main effect of time (P =0.000) for hunger, but there was no main effect of trial and no interaction effect

Trial	*Time*	*Mean*	*S.D*	*Repeated-measures two factor ANOVA P value*
Control	0	26.25	25.82	Trial: 0.410
	20	31.58	23.45	Time: 0.000
	40	36.41	21.66	Trial x Time: 0.254
	60	44.33	23.09	
	80	50.75	19.99	
	100	58.08	21.39	
	120	68.16	19.89	
Treadmill Exercise	0	19.58	14.97	
	20	25.25	17.94	
	40	32.00	18.06	
	60	41.33	20.54	
	80	47.50	18.68	
	100	55.50	22.07	
	120	67.75	16.79	
Resistance Exercise	0	19.41	14.96	
	20	23.83	15.84	
	40	28.16	15.10	
	60	35.33	13.78	
	80	44.83	13.55	
	100	51.75	17.54	
	120	58.41	17.22	
Combined Exercise	0	16.66	13.36	
	20	19.83	14.21	
	40	30.75	17.99	
	60	37.66	17.49	
	80	49.00	14.44	
	100	56.33	16.67	
	120	71.58	13.31	

Fullness

Baseline fulness did not differ significantly (Repeated Measures ANOVA,P=0.681) between trials. Two-factor ANOVA revealed a main effect of time (P= 0.000), and a trial and time interaction (P=0.047) for fullness, indicating that responses differedover time between trials. Post hoc analysis indicated significant differences between combined exercise trial and control trial at 120 min (P=0.028; Table 3).

Table 3: Fullness values over 120 min during the exercise and control trials. There was an effect of time (P= 0.000), and a trial x time interaction (P = 0.047) for fullness

Trial	*Time*	*Mean*	*S.D*	*Repeated-measures two factor ANOVA P value*
Control	0	69.83	27.85	Trial: 0.336
	20	65.66	26.59	Time: 0.000
	40	61.66	23.11	Trial x Time: 0.047
	60	53.66	25.09	
	80	47.91	25.58	
	100	40.91	25.83	
	120	36.66*	25.45	
Treadmill Exercise	0	78.91	19.19	
	20	70.33	25.56	
	40	56.75	25.33	
	60	48.83	23.58	
	80	41.16	21.31	
	100	37.00	20.98	
	120	26.25	15.09	
Resistance Exercise	0	77.58	17.21	
	20	69.58	23.84	
	40	63.41	22.92	
	60	51.08	21.64	
	80	51.50	19.07	
	100	42.75	22.51	
	120	34.00	19.41	
Combined Exercise	0	75.58	24.41	
	20	70.58	23.66	
	40	62.91	24.80	
	60	55.66	21.62	
	80	47.58	19.08	
	100	39.16	14.15	
	120	20.58*	10.43	

*Significant differences between combined exercise trial and control trial at 120 min after Bonferroni adjustment.

Desire to Eat

Baseline desire to eat did not differ significantly (Repeated Measures ANOVA, P=0.778) between trials.Two-factor ANOVA revealed a main effect of time (P= 0.000), and a trial and time interaction (p=0.046) for desire to eat, indicating that responses differed over time between trials. Post hoc analysis indicated significant differences in between combined exercise trial and resistance exercise trial at 120 minutes (P<0.05; Table 4).

Table 4: Desire to eat values over 120 min during the exercise and control trials. There was an effect of time (P= 0.000), and a trial x time interaction (P = 0.046) for desire to eat

Trial	*Time*	*Mean*	*S.D*	*Repeated-measures two factor ANOVA P value*
Control	0	22.75	19.15	Trial:
	20	27.58	17.73	0.502
	40	32.50	18.35	Time: 0.000
	60	44.50	23.23	Trial x
	80	47.50	21.21	Time:0.049
	100	56.08	24.18	
	120	61.58	22.57	
Treadmill Exercise	0	19.00	16.18	
	20	25.16	17.63	
	40	32.00	21.02	
	60	42.41	22.31	
	80	47.66	21.91	
	100	53.25	21.17	
	120	63.50	16.97	
Resistance Exercise	0	19.83	13.89	
	20	21.25	15.78	
	40	27.66	16.37	
	60	38.16	13.73	
	80	42.75	13.53	
	100	49.41	18.15	
	120	54.08*	17.53	
Combined Exercise	0	18.25	16.37	
	20	26.16	19.55	
	40	32.91	20.47	
	60	38.16	18.54	
	80	54.58	17.71	
	100	58.83	13.61	
	120	71.25*	12.67	

*Significantdifferences between combined exercise trial and resistance exercise trial at 120 min (P= 0.041) after Bonferroni adjustment.

Table 5: Prospective food consumption values over 120 min during the exercises and control trials. There was an effect of of time (P= 0.000), and a trial x time interaction (P = 0.014) for prospective food consumption

Trial	*Time*	*Mean*	*S.D*	*Repeated-measures two factor ANOVA P value*
Control	0	28.33	23.73	Trial:
	20	31.25	20.14	0.199
	40	37.50	21.80	Time: 0.000
	60	43.66	20.17	Trial x
	80	49.58	20.43	Time: 0.014
	100	57.75	21.63	
	120	63.33	19.07	
Treadmill Exercise	0	20.16	15.45	
	20	25.91	19.70	
	40	32.50	20.18	
	60	44.16	21.42	
	80	49.58	20.60	
	100	55.00	21.10	
	120	64.25	16.79	
Resistance Exercise	0	19.41	15.85	
	20	22.00	17.18	
	40	29.00	16.38	
	60	37.66	13.45	
	80	42.16*	14.37	
	100	48.08	18.60	
	120	55.08*	16.52	
Combined Exercise	0	23.75	19.95	
	20	28.08	20.49	
	40	35.33	20.13	
	60	41.41	20.21	
	80	54.83	16.48	
	100	61.33	14.32	
	120	75.75	11.20	

*Significantdifferences in resistance exercise trial from combined and treadmill exercise trials at 80 and 120 min (P< 0.05) after Bonferroni adjustment.

Prospective Food Consumption

Baseline prospective food consumption did not differ significantly (Repeated Measures ANOVA, P=0.433) between trials. Two-factor ANOVA revealed a main effect of time (P= 0.000), and a trial and time interaction (p=0.014) for prospective food consumption, indicating that responses differedover time between trials. Post hoc analysis indicated significant differences in resistance exercise trial from combined and treadmill exercise trials at 80 and 120 minutes (P<0.05; Table 5).

DISCUSSION

The aim of this study is to test the effects of acute resistance, treadmill and combined exercises on appetite marker ratings of healthy male individuals. According to the findings of the present research, exercise modes are not different from control in any of the appetite markers except for the feeling of satiety, and the differences between exercise modes are that, combined exercises decrease the feeling of satiety more than combined exercises, and caused desire to eat and prospective food consumption more than resistance exercises.

Recently many short and long term acute exercise studies have been conducted to determine the effects of acute exercise on appetite (Lofrano-Prado et al. 2012; Kawano et al. 2013; Bilski et al. 2013; Deighton et al. 2013; Alkahtani et al. 2014; Hagobian et al. 2013; Martins et al. 2014;

Thivel et al. 2014). King et al. (1994) reported a suppression of hunger and a delay in the onset of eating following high-intensity exercise (70 % VO_2max). Other studies have shown similar findings (King et al. 1994, 1995; Broom et al. 2007, 2009; Bilski et al. 2013; Deighton et al. 2013), and a recent meta-analysis demonstrated that energy intake during subsequent meals is not increased to match the energy expended during exercise (Schubert et al. 2012).

To the best of the researcher's knowledge, there have been only three researches on the effect of acute resistance exercise on appetite (Broom et al. 2009; Laan et al. 2010; Ozen et al. 2014). In the study conducted by Broom et al. (2009), eleven healthy male individuals participated in three different 8-hour trials with one-week intervals. These are resistance (at 12 RM 80%, 10 different exercises 12 reps 3 sets and 3-minute rests between sets; a 90-minute of exercise in total), aerobic (60-minute treadmill exercise at 70% of VO_2max), and control trial. The findings showed thathunger decreased in both exercise trials during exercise, but increased after exercise. Aerobic exercise resulted in a greater suppression of hunger than resistance exercise. Lean at al. (2010) conducted a similar research on nineteen young active adults involving separately conducted 35-minute aerobic and resistance exercises. On the contrary to the findings of this study, and Broom et al. (2009), Lean et al. (2010) found that hunger decreased only after aerobic exercise, and no significant changes were observed after resistance exercise.In a research conducted by Ozen et al. (2014) ten healthy young men participated in two trials of 90-minute resistance (at 10RM 80% 7 different exercises 10 reps 3 sets and 2-minute rests between sets; a 60-minute of exercise in total) and control with a one-week interval. They reported that appetite increased at a significant level during and after resistance exercise.

As can be seen above, the effects of acute exercise on appetite, either aerobic or resistance, are very contradictory.The possible reasons for these contradictions can be methodological differences such as exercise intensity, exercise duration, exercise type, gender, and participant selection. Even when there are some contradictory findings (Alkahtani et al. 2014; Martins et al. 2014), appetite is affected especially by exercise intensity (Bilski et al. 2013; Deighton et al. 2013; Williams et al. 2013). When the studies focusing on this subject are examined, despite some contradictory studies, generally, it can be seen that low or moderate intensity exercises do not affect hunger and food intake or increases them (Blundell et al. 2003; Stensel 2010; King 2010; Rumbold et al. 2011; Ozen 2012; Bilski et al. 2013). Researches on the effect of high intensity exercises (>70% of VO_2max) found that acute exercise suppresses hunger and energy intake (Blundell et al. 2003; King et al. 2011; Vatansever et al. 2011; Bilski et al. 2013). The possible cause for the suppression of hunger only after high intensity exercises is that, during high intensity exercise, the sympathetic nervous system activation increases, blood flow in splanchnic area decreases and most of the blood in the circulation is directed to active muscles (Ikeda et al. 2010).

CONCLUSION

One of the important findings of the present research is that combined exercise affected appetite markers negatively more than resistance exercise. Combined exercise decreased satiety and increased prospective food consumption more than resistance exercise. Concordantly, the researchers can claim that resistance exercise is the most appropriate exercise type for weight control. The reason for the negative effects of combined exercise is not exactly known, though the amount of consumed energy may be one of the possible reasons. Consequently, considering the effects on appetite markers, the researchers can suggest that resistance exercise is the most appropriate exercise type for weight control.

RECOMMENDATIONS

One of the limitations of the present research is that exercises were not isocaloric. Further researches with isoclaoric exercises may provide more accurate information on the relationship between the exercise mode and appetite. Thus, more research is needed to understand the impact of various modes and intensities of exercise and fitness level on appetite in different populations.

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