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Review

Exercise and Nutritional Strategies to Promote Weight Loss: A Narrative Review [1]

Richard B. Kreider *

Exercise and Sport Nutrition Lab, Human Clinical Research Facility, Department of Health & Kinesiology, Texas A&M University, College Station, Texas, USA; E-Mail: rbkreider@tamu.edu

* **Correspondence:** Richard B. Kreider; E-Mail: rbkreider@tamu.edu

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Abstract

Obesity has historically been thought to simply be related to an imbalance between energy intake and expenditure. Weight loss recommendations have traditionally focused on reducing energy intake, maintaining either a high-carbohydrate low-fat diet or vice versa, and increasing physical activity typically through low to moderate intensity exercise. More recently, genetic, physiological, and behavioral factors have also been found to play a significant role in the etiology of obesity. For this reason, the prevention and management of obesity through implementation of different types of exercise and diet intervention programs, behavioral interventions, and/or medical interventions are at the forefront of obesity research. As a result, we are beginning to see a paradigm shift from traditional weight loss and management approaches to personalized diet and exercise strategies. This purpose of this narrative review was to overview: 1.) the effects of physical activity on weight loss; 2.) the effects of diet and cardiovascular exercise on weight loss; 3.) the effects of high protein diet with resistance-exercise on weight loss; and, 4.) behavioral factors that contribute weight loss and maintenance.

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Keywords
Obesity; body composition; health

1. Introduction

Obesity is considered the leading cause of preventable death world-wide and is associated with a myriad of medical co-morbidities including arthritis, cataracts, certain types of cancer, diabetes, pulmonary abnormalities, and urinary incontinence [1-4]. The prevalence of obesity has been increasing at all age levels. For example, Ogden and associates [5] reported that the incidence of obesity in the United States among adolescents aged 12 to 19 years has increased from 10.5% between 1988-1994 to 20.6% in 2013-2014. Additionally, extreme obesity among children aged 6 to 11 years increased from 3.6% to 4.3% while extreme obesity increased from 2.6% to 9.1% in adolescents aged 12 to 19 years during this time period. The age-standardized prevalence of obesity in United States adults also increased from 15% in 1976-1980 to 38% in 2013-2014 [6, 7]. Finally, according to the Center for Disease Control (CDC)'s 2007-2010 National Health and Nutrition Examination Survey, 41% of individuals in the United States aged 65 - 74 years old and 28% of those above age 75 were obese [8]. Consequently, obesity and associated morbidities are increasing in prevalence and identifying strategies to promote healthy and effective weight loss and maintenance continues to be a significant worldwide health challenge [1].

Historically, weight loss recommendations have focused on reducing energy intake; maintaining a high carbohydrate, low glycemic, and low fat diet; and, increasing physical activity (e.g., walking). While these approaches are effective, there is considerable variability in the magnitude of weight loss among participants following the same diet and/or exercise program [9, 10]. Additionally, many individuals regain the amount of weight lost within a year or so after dieting [11, 12]. More recently, there has been interest in determining the effects of genetics and behavioral factors on the etiology of obesity [1, 11, 12]. This interest has led to the study of whether different types of diet, exercise, and/or behavioral interventions may be more effective in promoting weight loss and maintenance than traditional programs [1]. Additionally, there has been interest in understanding whether genotype plays a role in promoting effective weight loss and maintenance [10, 13-19]. For example, there has been a considerable amount of research that has evaluated whether consuming higher protein and low fat diets promote more beneficial changes in body composition during exercise and/or diet interventions [20-22]. As a result, we are beginning to see a paradigm shift from traditional weight loss and management approaches to more personalized diet and exercise interventions [1, 13, 23, 24]. The purpose of this paper is to overview: 1.) the effects of physical activity on weight loss; 2.) the effects of diet and cardiovascular exercise on weight loss; 3.) the effects of a high protein diet with resistance-exercise on weight loss; and, 4.) behavioral factors that contribute weight loss and maintenance.

2. Effects of Physical Activity on Weight Loss

2.1 Cardiovascular Exercise

Cardiovascular or "aerobic" exercise (e.g., 150-250 min/week of moderate intensity exercise) has been recommended to help obese individuals maintain weight loss and/or promote weight loss while dieting [25]. Moreover, weight loss success has been reported to be improved while participating in >250 min/week of moderate intensity exercise [25]. A recent review by Chin [26] summarized some of the more recent literature related to the impact of physical activity on weight loss and body composition (see Table 1). For example, Irwin et al. [27] evaluated the effects of a one-year of aerobic exercise (225 min/week at 60-75% max heart rate) on weight loss in 168 post-menopausal women. The researchers reported that exercisers lost -1.3 kg of weight and -1.2% of fat compared to 0.1 kg and -0.2% body fat in controls. Nishijima and coworkers [28] reported that men and women participating in a 6-month exercise program (80-160 min/week at 70% of VO_{2peak}) promoted a -1.88 kg reduction in body mass compared to -0.28 kg in controls. Alves et al. [29] evaluated the effects of performing cardiovascular exercise (3 x 50-min sessions per week at 40-60% of heart rate reserve) for 6-months on weight loss in 156 obese women. The researchers reported the women lost an average of -1.26 kg in body mass compared to 0.4 kg in the control group. Musto and assistants [30] evaluated the effects of progressively increasing daily step count to 10,000 steps/day on weight loss in 77 overweight women. Results revealed that women in the walking program lost -0.8 kg compared to gaining 0.2 kg in the control group. David and colleagues [31] evaluated the effects of following a 3-month walking intervention program using a mobile phone application on weight loss in 71 post-menopausal women. The researchers found that the women following the walking program lost -0.93 kg during the intervention. Willis and colleagues [32] evaluated the effects of walking/running approximately 12 miles/week at 65% to 80% of VO_{2peak} for 8 months on changes in body mass and composition in 38 overweight or obese adults. Participants lost -1.76 kg and -1.01% body fat. Finally, Donnelly and associates [33] evaluated the effects of adherence to an exercise program designed to expend either 400 or 600 kcals/session at 70% - 80% of maximal heart rate for 10 months in 141 overweight and obese men and women. The researchers reported that individuals on the 400 kcal/session program lost -3.9 kg compared to -5.2 kg in the 600 kcal/session group and 0.5 kg in the control group. This was associated with a -2.9%, -4.3%, and -0.6% loss in percent body fat, respectively. Results of these studies suggest that overweight and/or obese individuals participating in a 3 to 12 month, moderate intensity, cardiovascular exercise program primarily consisting of walking promoted an average of 0.32 ± 0.13 kg/month of weight loss and -0.17±0.18 % body fat/month.

Table 1 Changes in body mass and composition from cardiovascular exercise.

Reference	Population	Duration (mo.)	Intervention	Δ BM (kg)	Δ Body Fat (%)
Irwin et al. [27]	87 F (≥25 BMI, 50-75 yrs.)	12	60-75% max HR, 225 min/week	-1.3 [-2.0, -0.5]*	-1.2 [-1.6, -0.8]*
Nishijima et al. [28]	281 M & F (≥30 BMI, 40-89 yrs.)	6	70% VO_{2peak}, 80-160 min/week	-1.88 [-2.14, -1.62]*	_

Alves et al. [29]	78 F (≥ 25 BMI, 20-60 yrs.)	6	40-60% HRR, 150 min/week	-1.26 [-1.78, -0.81]*	_
Musto et al [30]	43 F (30.4 BMI, 46 yrs.)	3	Walking, steps ↑ 10%/week until 10,000/week, ↑3%/week thereafter	-0.8 [-1.35, -0.04]*	-
David et al. [31]	71 F (25-40 BMI, < 75 yrs.)	3	Walking 10,000 steps/day	-0.93	-
Willis et al. [32]	38 overweight or obese adults	8	~12 miles/week at 65-80% VO_{2peak}	-1.76	-1.01
Donnelley et al. [33]	19 M (25-40 BMI, 18-30 yrs.)	10	600 kcal/session, 70-80% max HR, 5/week	-5.9 [-9.1, -2.7]*	-4.5 [-6.9, -2.2]*
	18 M (25-40 BMI, 18-30 yrs.)	10	400 kcal/session, 70-80% max HR, 5/week	-3.8 [-6.6, -0.9]*	-2.7 [-4.9, -0.4]*
	18 F (25-40 BMI, 18-30 yrs.)	10	600 kcal/session, 70-80% max HR, 5/week	-4.4 [-6.5, -2.3]*	-4.1 [-6.1, -2.1]*
	18 F (25-40 BMI, 18-30 yrs.)	10	400 kcal/session, 70-80% max HR, 5/week	-4.1 [-6.1, -2.0]*	-3.2 [-4.9, -1.6]*

Adapted from Chin et al. [26]. Data are reported mean changes from baseline [95% confidence interval] (if available). Δ=change from baseline, BM=body mass, BMI=body mass index, F=female, HR=heart rate, HHR=heart rate reserve, kcal=kilocalories, max=maximal, min=minutes, mo.=months, M=male, VO_{2peak}= peak oxygen uptake, yrs.=years. * $P < 0.05$ compared with changes over-time in control group.

2.2 Resistance Exercise

There have also been several studies that have evaluated the effects of resistance-exercise alone on weight loss and/or body composition (see Table 2). Kirk et al. [34] evaluated the effects of a 6-month resistance-exercise program intervention (1 set, 3 days/week, 3-6 repetitions, 9 exercises) in sedentary and overweight adults. The researchers reported that those involved in resistance-exercise gained 2.5 kg in body mass, 1.5 kg of fat free mass, 0.9 kg in fat mass, and 0.3% body fat compared to 2.4 kg, -0.3 kg, 2.3 kg, and 2.1% in the control group respectively. Kerksick and associates [35] found that participation in an 8-week, split-body, linear periodized heavy resistance training program increased body mass by 0.7 kg, fat free mass by 0.9 kg, fat mass by 0.5 kg, and percent body fat by 0.4 % in college-aged men while middle-aged men experienced a 0.5 kg increase in body mass, a 1.1 kg increase in fat free mass, a -0.5 kg reduction in fat mass, and a -0.7% reduction in percent body fat. Willis and coworkers [32] evaluated the effects of resistance exercise training (3 sets/day, 8-12 repetitions/set, 3 days/week, for 8 months) on changes in body mass and body composition in 44 overweight or obese men and women. Resistance training promoted a -0.8 kg loss in body mass, a 1.1 kg increase in fat free mass, and a -0.7% reduction in body fat percent. Moghadasi and coworkers [36] compared the effects of resistance or endurance training on weight loss and body composition. Young sedentary men (n=29) served as controls or participated in resistance training (2-4 sets, 65% - 80% of 1 repetition maximum, 8 exercises, 3 days/week) or endurance training (20 - 34 min/day, 60% - 80% of maximal heart rate, 3 days/week) for two months. The researchers found that resistance training promoted a 0.4 kg increase in body mass and 0.2% reduction in body fat percentage compared to -1.3 kg and -2.4% with endurance training and 0.1 kg and -0.04% in the control group. Finally, Roberts et al. [37] evaluated the effects of 3 months of resistance training (2 weeks of 12-15 repetitions, 5 weeks of 8-12 repetitions, 5 weeks of 6-8 repetitions in a split upper and lower body program consisting of 15 exercises) on changes in body mass and composition. Resistance training increased body mass by 1.8 kg and lean mass by 2.7 kg while decreasing fat mass by -1.0 kg compared to 0.02 kg, -0.45 kg, and -0.82 kg, respectively, in the control group. The average change observed in these studies was in 0.27±0.25 kg/month in body mass, 0.42±0.31 kg/month of fat-free mass, and -0.06±0.18 %/month of body fat.

Table 2 Changes in body mass and composition from resistance exercise.

Reference	Population	Duration (mo.)	Intervention	Δ BM (kg)	Δ FFM (kg)	Δ Body Fat (%)
Kirk et al. [34]	22 M & F (27.7 BMI, 21 yrs.)	6	Supervised, 3 days/week, 1 set x 9 exercises at 85-90% 1RM	2.5 [1.5, 3.4]	1.5 [0.5, 2.4]	0.3 [-0.5, 1.2]*
Kerksick et al. [35]	24 CA men (18-22 yrs.)	2	2 x upper and 2 x lower workouts/week; 3-6 sets at a 10-RM weeks 1-4, 8-RM for weeks 5-8.	0.7	0.9	0.4
	25 MA men (35 - 50 yrs.)			0.5	1.1	-0.7
Willis et al. [32]	44 M & F (25-35 BMI, 18-70 yrs.)	8	8-12 reps/set, three sets/day, 3 days/week	0.8	1.1	-0.7
Moghadasi et al. [36]	10 M (23.5 BMI, 21-29 yrs.)	3	8-12 reps of 65-80% 1-RM, 50-60 min/day, 3 days/week	0.4 [-1.2, 2.0]	-	-0.2 [-1.8, 1.4]
Roberts et al. [37]	28 M (≥ 27 BMI, 18-35 yrs.)	3	Increasing intensity to reach 6-8 reps/set, 1h/session, 3 days/week	1.8 [0.0, 3.0]	2.7 [2.0, 3.4]	-1.0 [-2.9, -0.4]

Adapted from Chin et al. [26] Data are reported mean changes from baseline [95% confidence interval] (if available). Δ=change from baseline, BM=body mass, BMI=body mass index, CA=college age, F=female, FFM=fat-free mass, h=hour, M=male, MA=middle age, min=minutes, mo.=month, reps=repetitions, RM=repetition maximum, yrs.=years. * $P < 0.05$ compared with changes over-time in control group.

3. Effects of Diet and Cardiovascular Exercise on Weight Loss

As the above discussion notes, exercise alone provides a modest reduction in body mass and fat mass. The combination of dieting with exercise intervention provides a much greater impact (see Table 3). For example, Goodpaster et al. [38] evaluated the efficacy of diet intervention (1,200-2,100 kcals/day) with and without exercise (60 min of moderate intensity walking, 5 days/week) on weight loss efficacy in 101 African American participants. One group was randomized to diet and physical activity for the entire 12 months while another group dieted for 6-months prior to initiating exercise training. Results revealed that participants who dieted and exercise for the entire year lost -12.1 lbs. and -2.9% body fat with the majority of the weight (10.9 lbs. or 90%) and percent body fat (2.9% or 83%) observed during the initial 6 months of dieting and exercise. Conversely, those who dieted only during the first 6 months prior to initiating exercise lost 9.9 lbs. and 2.7% body fat with most of the weight (-8.2 lbs. or 83%) and body fat (-1.7% or 76%) observed during the first 6 months when participants only dieted. Similarly, Foster-Schubert and associates [39] conducted a year-long study in 439 overweight post-menopausal women to determine the effects of diet, exercise, and the combination on weight loss. Participants either made no lifestyle change (control group), followed a low-fat diet (1,200-2,000 kcals/day, <30% fat), a moderate-intensity cardiovascular exercise program (≥45 min of moderate-to-vigorous intensity exercise [e.g., walking, cycling, cardiovascular machines], 5 days/week), or the combination of both diet and exercise interventions. Results revealed that participants in the control group lost -0.7 kg (-0.8%) of body mass, -0.4 kg (-1.0%) of fat mass, -0.1 kg (-0.1%) of fat-free mass, and -0.2% (-0.3%) body fat percentage. Those who exercised only lost -2.0 kg (-2.4%) of body mass, -2.1 kg (-5.3%) of fat mass, and -1.6% (-3.3%) of body fat percentage while gaining 0.3 kg (0.7%) fat-free mass. Those who dieted only lost -7.1 kg (-8.5%) of body mass, -6.1 kg (-15.6%) of fat mass, -0.8 kg (-1.9%) fat-free mass, and -1.2% (-8.9%) of body fat percentage. Finally, those who dieted and exercised lost -8.9 kg (-10.8%) of body mass, -8.2 kg (-20.8%) of fat mass, -0.4 kg (-1.1%) fat-free mass, and 5.9% (-12.4%) in body fat percentage. The average change in body composition for these studies was -0.94±0.7 kg/month in body mass, -0.76±0.5 kg/month in fat mass, 0.17±0.2 kg/month in fat-free mass, and -0.30±0.2 %/month in body fat. Collectively, these studies indicate that the majority of weight and fat loss observed occurs with dieting rather than exercise but that the best results are observed when combining diet and exercise. Additionally, individuals who perform cardiovascular exercise during a diet and weight loss intervention typically observe a reduction in fat-free mass.

Table 3 Changes in body mass and body composition from diet + exercise interventions.

Reference	Population	Duration (mo.)	Intervention	Δ BM (kg)	Δ FM (kg)	Δ FFM (kg)	Δ Body Fat (%)
Goodpaster et al. [38]	63 AA M & F (35-40 BMI, 30-55 yrs.)	6	Diet (1,200-2,100 kcals/day)	-8.2	-5.9	-2.1	-1.7
	67 AA M & F (35-40 BMI, 30-55 yrs.)	6	Diet (1,200-2,100 kcals/day) + AE (moderate intensity, 300 min/week)	-10.9	-8.7	-2.4	-2.9
Foster-Schubert et al. [39]	118 Asian-A F (≥ 23 BMI, 50-75 yrs.)	12	Diet (1,200-2,000 kcal/day, until achieved 10% WL in 6 months	-7.1	-6.1	-0.8	-1.2

	117 Asian-A F (≥ 23 BMI, 50-75 yrs.)	12		AE (70-85% max HR 225 min/week)	-2	-2.1	0.3	-1.6
	116 Asian-A F (≥ 23 BMI, 50-75 yrs.)	12		Diet + AE	-8.9	-8.2	-0.4	-5.9
	87 Asian-A F (≥ 23 BMI, 50-75 yrs.)	12		No Diet or Exercise	-0.7	-0.4	-0.1	-0.2

Adapted from Chin et al. [26] Data are reported mean changes from baseline. AA=African-American, Asian-A=Asian-American, BM=body mass, BMI=body mass index, mo=month, Δ=change from baseline, FM=fat mass, FFM=fat-free mass, M=male, F=female, yrs.=years, AE=Aerobic Exercise, WL=Weight Loss, HR=heart rate, min=minute.

4. Effects of High Protein Diet with Resistance-Exercise on Weight Loss

4.1 Rationale

As noted above, the majority of weight lost initially during an exercise and/or diet intervention is primarily due to diet intervention rather than exercise. The reason for this is that overweight and obese individuals typically have low exercise capacity so they generally can only expend 200 to 300 kcals per 30 - 40 min exercise session. Therefore, most of the negative energy balance comes from diet until individuals become fit enough to be able to increase exercise energy expenditure [1, 12]. However, if individuals reduce energy intake excessively and/or only participate in low to moderate intensity cardiovascular exercise training, they often lose muscle mass and/or experience a reduction in resting energy expenditure [1, 13, 21, 40-45]. Reductions in fat-free mass and/or resting energy expenditure as a result of dieting has been suggested to be a factor in weight regain [11, 12, 25, 46-48]. For this reason, it's generally recommended that individuals lose no more than 0.5-1 kg per week (<1% of body mass per week) during a diet and/or exercise intervention [49]. However, the goal for effective weight loss should be to promote fat loss while maintaining muscle mass during a diet intervention rather than focusing on loss of total body mass [1, 21, 40-42, 44, 50]. Replacing some dietary carbohydrate and/or fat with protein while on a hypo-energetic diet has been recommended as a way to preserve muscle mass during weight loss [20, 21, 41-43, 51, 52]. Additionally, while low to moderate intensity cardiovascular exercise (e.g., walking) has generally been recommended, there has been interest in determining whether intermittent high intensity exercise [53-57] and/or resistance-exercise training during weight loss interventions may help preserve muscle mass in individuals attempting to lose weight [12, 21, 41-43, 58-60].

4.2 Diet Intervention Studies

Our research group has conducted a number of studies as part of the Curves Women's Health & Fitness Initiative to determine whether increasing the proportion of protein consumed during a hypo-energetic diet intervention with circuit-style resistance training affects weight loss outcomes [13, 21, 40-45, 61]. In our first study, Kerksick and colleagues [41] evaluated the effects macronutrient variation on weight loss success in 161 sedentary, obese, and pre-menopausal women. Participants were assigned to either a no exercise + no diet control group, a no diet + exercise group, or one of four diet + exercise groups. Diet assignments included a high energy, high carbohydrate, low protein diet (HED: 2,600 kcals; 55:15:30% [carbohydrate:protein:fat] for 14-weeks) for women presenting with low resting energy expenditure. Women with normal resting energy expenditure were assigned a hypo-energetic diet for 10-weeks (1,200 kcals/day for 2-weeks followed by 1,600 kcals/day for 8-weeks). Hypo-energetic diet interventions included a very low carbohydrate, high protein diet (VLCHP: 7:30:63%), a low carbohydrate, moderate protein diet (LCMP: 50:20:30%), or a standard high carbohydrate, low protein diet (HCLP: 55:15:30%). After the 10-week weight loss intervention, all diet groups followed a maintenance diet for 4-weeks (2,600 kcals/day; 55:15:30% with intermittent reductions in energy intake to 1,200 kcals/day for 2-days during the maintenance period. Participants in the exercise groups performed a pneumatic resistance-based, circuit training program under supervision three times per week. Results revealed that those following the VLCHP, LCHP and LPHC diets experienced similar but significant reductions in body mass when compared to other groups. Fat loss expressed as mean [95% Confidence Intervals] changes from baseline revealed that fat loss was significantly greater in VLCHP (-4.2 kg [-5.2, -3.2], p<0.005), LCMP (-2.9 kg [-4.0, -1.9], p<0.001) and HPLC (-2.0 kg [-3.8, -2.1], p<0.001) groups. Reductions in percent body fat were also significantly greater in VLCHP, LCMP and HCLP groups. The initial 2-weeks of dieting (1,200 kcals/day) decreased relative resting energy expenditure similarly in all hypo-energetic diet groups but was increased to near baseline values when consuming 1,600 kcals/day. Favorable but non-significant mean changes occurred in lipid panels, glucose and homeostatic insulin resistance ($HOMA_{IR}$). Leptin levels significantly decreased in all groups except controls after 2-weeks of dieting (1,200 kcals/day) and remained lower throughout the 14-week program. These findings suggest that the exercise alone appears to have minimal impact on measured outcomes with positive outcomes apparent when exercise is combined with a hypo-energetic diet. Moreover, that greater improvements in body composition occurred when carbohydrate was replaced in the diet with protein.

While these results were positive, we observed a greater than desired reduction in resting energy expenditure during Phase I of the diet and continued to observe weight loss during the maintenance phase. Therefore, we conducted a similar follow-up study [42] with the exception that participants only followed Phase I of the diet (1,200 kcals/day) for 1-week and reduced energy intake to 1,200 kcals/day for 2-days only if they gained 3 lbs. during the Phase III maintenance phase. In this study, 141 sedentary, obese women were randomized to either no diet + no exercise control group, a no diet + exercise only group, or one of four diet + exercise groups (high-energy diet [HED; 55:15:30%], very low carbohydrate, high protein diet [VLCHP: 7:63:30%], low carbohydrate, moderate protein diet [LCMP: 20:50:30%], or high carbohydrate, low protein diet group [HCLP: 55:15:30%]) while participating in a supervised circuit-based resistance-exercise training program (3 days/week). Participants on the hypo-energetic diets consumed 1,200 kcals/day for 1-week (Phase I), 1,600 kcals/day for 9 weeks (Phase II), and 2,600 kcals/day (Phase III) with intermittent reductions in energy intake (1,200 kcals/day) only if they experienced a 3 lbs. increase in body mass. Results revealed that participants following a hypo-energetic diet and exercise program observe significantly greater waist circumference, body mass, and body composition changes. For example, after 10-weeks of following the program, weight loss was greater in the diet groups (VLCHP: -4.7±3.2 kg; p<0.001; LCMP: -3.6±2.9 kg; p<0.001; HCLP: -3.9±4.5 kg; p<0.001). After 14-weeks, changes in body mass were greater among diet groups (VLCHP: -5.0±4,2 kg; p<0.001; LCMP: -3.7±3.3 kg; p<0.01; HCLP: -3.6±3.8 kg; p<0.01) compared to controls (0.5±2.9 kg). Moreover, after 10-weeks, participants dieting experienced reductions in fat mass (VLCHP: -3.6±2.1 kg; p<0.001; LCMP: -3.0±2.6 kg; p<0.001; and, HCLP: -2.7±2.6 kg; p<0.001) which were maintained after 14-weeks (VLCHP: -3.7 2.9 kg; p<0.001; LCMP: -3.5±4.7 kg; p<0.001; and HCLP: -2.9±2.9 kg; p<0.001). Fat-free mass was well-maintained and while energy restriction initially reduced energy expenditure, it returned to baseline values after 10-weeks of diet and exercise. Serum leptin decreased in all energy restriction + exercise groups after 14-weeks while insulin and $HOMA_{IR}$ values decreased in the VLCHP group. It was concluded that macronutrient distribution may impact circulating levels of insulin and overall ability to improve body composition and strength in obese women who follow regular exercise. These findings have served as the hypothesis generator for next studies that not only have shown similar results but also have evaluated other dietary interventions and hormones controlling appetite or energy expenditure in overweight/obese individuals [62-66].

We then sought to determine if increasing protein intake with resistance-training would promote greater fat loss while preserving fat-free mass and resting energy expenditure in older women [21]. In this study, 54 overweight, obese, and older females were randomly assigned to an exercise-only group (E), an exercise plus hypo-energetic higher carbohydrate (HC) diet, or a higher protein hypo-energetic diet with exercise (HP). Participants followed their respective diet plans (1,200 kcals/day for 1-week, 1,600 kcals/d for 9-weeks, and 2,100 kcals/d for 4-weeks) and performed a supervised circuit-style resistance exercise program 3 days/week. Results revealed that after 14-weeks, participants in the HP group experienced significantly greater reductions in weight (E −1.3±2.3, [−2.4, −0.2]; HC −3.0±3.1 [−4.5, −1.5]; HP −4.8±3.2, [−6.4, −3.1] %, p=0.003), fat mass (E −2.7±3.8, [−4.6, −0.9]; HC −5.9±4.2 [−8.0, −3.9]; HP −10.2±5.8 [−13.2, -7.2] %, p<0.001), and body fat percentage (E −2.0±3.5 [−3.7, −0.3]; HC −4.3±3.2 [−5.9, −2.8]; HP −6.3±3.5 [−8.1, −4.5] %, p=0.002) with no significant reductions in fat-free mass or resting energy expenditure over time or among groups. Significant differences were also observed in leptin (E −1.8±34 [−18, 14]; HC 43.8±55 [CI 16, 71]; HP −26.5±70 [−63, −9.6] ng/mL, p=0.001) and adiponectin (E 43.1±76.2 [6.3, 79.8]; HC −27.9±33.4 [−44.5, −11.3]; HP 52.3±79 [11.9, 92.8] μg/mL, p=0.001) once again showing that this diet and exercise intervention positively affected appetite-related hormone levels. These findings indicated that a higher protein diet while participating in a resistance-based exercise program promoted more favorable changes in body composition compared to a higher carbohydrate diet in older women.

After conducting these and other studies, we observed that while mean changes in body composition were impressive, there was significant variation in individual response to similar diet and exercise interventions. Over the last 10-15 years, there has been interest in determining whether variations in fat-related gene phenotype could explain some of the variability in weight loss success and whether alignment of diet type to gene phenotype may lead to greater weight loss success [9, 10, 14, 15, 24, 67]. To examine that issue, we had fat-related genotype (FABP2rs1799883, PPARG2rs1801282, ADRB3rs4994C3, ADRB2rs1042713, rs1042714) determined in 63 sedentary and obese women using a direct-to-consumer genetic screening kit purported to promote greater weight-loss success through dietary recommendations based on these genes [13]. Participants were randomly assigned to follow a moderate-carbohydrate (MC: 30:45:25%) or lower-carbohydrate (LC: 20:45:35%) hypo-energetic diets (1,400 kcals/day for 1 -week and 1,500 kcals/day for 23-weeks) that aligned (A) or did not align (NA) with genotype while participating in a resistance-training (4 days/week) and walking program (10,000 steps/day on non-resistance-training days). Results revealed that participants in the LC group experienced greater improvements in percent changes in body composition (weight: MC -3.32 [-1.4, -5.2], LC -5.82 [-4.1, -7.6]; fat mass: MC -7.25 [-3.2, -11.2], LC -10.93 [-7.3, -14.5]; fat-free mass: MC -0.32 [1.4, -2.0], LC -1.48 [0.7, -3.0]; body fat percentage: MC -4.19 [-1.6, -6.8], LC -5.60 [-3.3, -7.9] %). However, no significant differences were observed between genotype groups (weight: A -5.00 [-3.3, -6.7], NA -4.14 [-2.2, -6.1]; fat mass: A -10.15 [-7.0, -13.6], NA -8.02 [-4.0, -12.0]; fat-free mass: A -1.23 [0.3, -2.8], NA -0.56 [1.12, -2.3]; body fat: A -5.28 [-3.0, -7.6], NA -4.51 [-1.9, -7.1] %). We concluded that adherence to this exercise and weight-loss program promoted improvements in body composition and health outcomes. Additionally, while individuals following the LC diet experienced greater benefits, alignment of these diets to this specific genetic profile did not promote greater health outcomes. Interestingly, a recent study showed that the rs1052700 polymorphism of the perilipin 1 gene was associated with a differential response to fat mass reduction after a 12-week diet + exercise intervention in overweight/obese adult women [68]. However, the research in this field is in its infancy and additional work is needed to determine if these or other genes may help predict weight loss success with different types of diets and exercise programs before conclusions can be drawn.

4.3 Comparison Effectiveness Studies

Based on these findings, we decided to compare the effects of following the HCLP diet while participating in a structured resistance-based exercise program to a high carbohydrate / low protein meal replacement diet with exercise recommendations [44]. In this study, 77 sedentary, obese women were randomly assigned to follow a structured diet and resistance-based exercise and walking program or an exercise recommended program. The structure program diet consisted of consuming 1,200 kcals/day for 1-week, 1,600 kcals/day for 9-weeks, and 2,100 kcals/day for 14-weeks of a 55:15:30% diet. The non-structured diet intervention involved replacing breakfasts and snacks with cereal or food bars with exercise encouragement for 24-weeks. Results revealed that during the 10-week weight loss phase, moderate and vigorous physical activity levels were significantly higher in the structured diet and exercise group with no differences observed between groups in daily energy intake. The structured diet and exercise group lost more weight (−3.1±3.7 vs −1.6±2.5 kg; p=0.03); fat mass (−2.3±3.5 vs −0.9±1.6 kg; p=0.02); centimeters from the hips (−4.6±7 vs −0.2±6 cm; p=0.002) and waist (−2.9±6 vs −0.6±5 cm; p=0.05); and, experienced a greater increase in peak aerobic capacity than participants in the meal replacement diet group with encouragement to exercise. Moreover, during the 24-week maintenance phase, participants in the structured diet and exercise group maintained greater moderate and vigorous physical activity levels, weight loss, fat loss, and saw greater improvement in maximal aerobic capacity and strength. We concluded that a structured diet and exercise program appears to be more efficacious in promoting and maintaining weight loss and improvements in markers of health and fitness compared to a meal replacement diet program with encouragement to increase physical activity.

We then decided to compare this exercise and diet intervention approach to other popular diet intervention programs. In the first comparative effectiveness study [69], 51 sedentary women were randomized to participate in the Curves® (C) or Weight Watchers® (W) weight loss programs for 16-weeks. Participants in the C program followed a 1,200 kcal/day diet for 1-week and 1,500 kcal/day diet for 3-weeks (30:45:25%). The participants then ingested 2,000 kcals/d for 2-weeks (45:30:25%) and repeated this diet while participating in the Curves with Zumba® resistance-based exercise program 3 days/week. Remaining participants followed the W point-based diet program, received weekly counseling, and were encouraged to exercise. Body composition and resting energy expenditure measurements were obtained at 0, 4, 10, & 16 weeks. Data are presented as changes from baseline for the C and W groups, respectively, after 4, 10, and 16 weeks. Results revealed that women in both groups lost a similar amount of weight (C -2.4±2.1, -4.4±3.6, -4.9±4.0; W -2.7±1.3, -5.3±2.4, -6.2±4.1 kg, p=0.31). However, fat mass loss (C -3.9±5.5, -4.6±5.3, -6.4±5.9; W -0.4±5.7, -2.1±6.7, -2.9±7.8 kg, p=0.09) and reductions in percent body fat (C -3.3±5.2, -3.2±4.6, -4.7±5.4; W 0.6±6.7, -0.6±8.3, -1.4±8.1 %, p=0.054) tended to be greater in the C group while fat free mass was increased in the C while decreasing in the W group (C 1.5±4.3, 0.5±3.7, 1.3±4.0; W -1.8±5.4, -2.4±5.8, -2.5±5.1 kg, p=0.01). Resting energy expenditure values increased over time in both groups and were non-significantly higher in the C group (C 0.9±2.2, 1.4±2.3, 1.3±1.9; W 0.6±2.0, 0.7±2.0, 0.6±2.3 kcals/kg/d, p=0.19). Results indicated that 16-weeks of participation in the C program that involved a more structured meal plan based diet and supervised exercise program promoted more favorable changes in body composition than participation in the W program that involved adherence to a point based diet, weekly counseling, and encouragement to increase physical activity.

We then sought to compare the effects of the Curves Complete® 90-day challenge diet (CC) and exercise program to other commercially available and popular diet programs [40]. The goal of this study was to compare the CC program, which incorporates exercising and diet, to programs advocating exercise with either diet counseling (Weight Watchers Points Plus (W), or meal-provided diets with exercise recommendations (Jenny Craig® At Home [JC] and Nutrisystem® Advance Select [NS] programs compared to controls. In this study, 133 sedentary, overweight women were randomized into treatment groups for 12 weeks. Results revealed a significant weight loss for all groups except the control group (CC -4.32 kg [-5.75, -2.88]; WW -4.31 kg [-5.82, -2.96]; JC -5.34 kg [-6.86, -3.90]; NS -5.03 kg [-6.49, -3.56]; and control 0.16 kg [-1.56, 1.89]). Reduced metabolic syndrome prevalence was observed at follow-up for CC (35% vs. 14%1) but not WW (31% vs. 28%), JC (37% vs. 42%), NS (39% vs. 50%), or control (45% vs. 55%). While all groups improved relative fitness because of weight loss, only the CC group improved absolute fitness (L/min). It was concluded that commercial programs offering concurrent diet and exercise programming appear to offer greater improvements in metabolic syndrome prevalence and cardiovascular function after 12-weeks of intervention.

4.4 Impact on Markers of Health Risk

Given we have conducted a number of similar studies; we began evaluating combined data sets to determine if additional insights could be gained. In our first analysis [43], we examined whether women with insulin resistance responded more favorably to a carbohydrate restricted diet while participating in a circuit-based resistance-training program. Sedentary and overweight or obese women (n=221) who were 46.5±12 years; 90.3±16 kg; and had a BMI of 33.8±5 kg/m^2 participated in a 10-week supervised exercise and weight loss program. The fitness program involved circuit-style resistance training performed 3 days per week. Subjects were prescribed low-fat (30%) iso-energetic diets that consisted of 1,200 kcals/day for 1-week (Phase 1) and 1,600 kcals/day for 9-weeks (Phase II) with higher proportions of carbohydrate (HC) or protein (HP). Participants were retrospectively stratified into lower (LH) or higher (HH) than 3.5 $HOMA_{IR}$ groups. Results revealed that baseline $HOMA_{IR}$ levels in the LH group were significantly lower than those in the HH group (LH, 0.6±0.7; HH, 6.3±3.4; p=0.001). Diet and training significantly decreased body mass (-3.5±3 kg), fat mass (-2.7±3 kg), blood glucose (-3%), total cholesterol (-4.5%), low-density lipoproteins (-5%), triglycerides (-5.9%), systolic blood pressure (-2.6%), and waist circumference (-3.7%), while increasing peak aerobic capacity (7.3%). Subjects in the HP group experienced greater weight loss (-4.4±3.6 kg vs -2.6±2.9 kg), fat loss (-3.4±2.7 kg vs -1.7±2.0 kg), reductions in serum glucose (3% vs 2%), and decreases in serum leptin levels (-30.8% vs -10.8%) than those in the HC group. Participants in the HH (-14.1%) and HP-HH (-21.6%) groups observed the greatest reduction in serum blood glucose. It was concluded that a carbohydrate-restricted diet promoted more favorable changes in weight loss, fat loss, and markers of health in obese women who initiated an exercise program compared with a diet higher in carbohydrate. Additionally, obese women who initiated training and dieting with higher $HOMA_{IR}$ levels experienced greater reductions in blood glucose following an HP diet.

In a larger retrospective study on 661 women (46±11 yrs.), we examined whether adherence to higher carbohydrate (HC) or higher protein (HP) diets while participating in this exercise program affected markers of metabolic syndrome [45]. Results revealed that both groups experienced significant weight loss, improvements in fitness, and reductions in metabolic syndrome (MetS) prevalence from baseline to follow-up (HP: 49% to 42%, HC: 42% to 36%, both p<0.01) (PRO: 49% to 42%, CHO: 42% to 36%, both P < 0.01). MetS z-score improvement (approximately 66.5%) was similar for both groups with no significant differences between diets in waist circumference (-0.28±0.02 vs. -0.28±0.025 cm), glucose (-0.07±0.03 vs. -0.08±0.04 mM), triglycerides (-0.16±0.04 vs. -0.09±0.04 mM), high-density lipoprotein cholesterol (-0.21±0.03 vs. -0.19±0.04 mM), and systolic blood pressure (-0.16±0.4 vs. -0.24±0.05 mmHg). Diastolic blood pressure showed a minor advantage for the HP group (-0.14±0.05 vs. -0.30±0.05 mmHg, p=0.02). When stratified by BMI, those with morbid obesity did not show a significant improvement in MetS while following a HP focused diet. However, caution is warranted given the exploratory nature of this analysis. We concluded that that a low-moderate calorie diet partitioned for carbohydrate and protein preference is equally effective when combined with a structured exercise program for reducing the prevalence of MetS prevalence in overweight and obese women.

Finally, we conducted a retrospective analysis of how relative protein intake affected weight loss in 661 women who participated in this research [70]. Data were examined relative to tertiles of protein ingestion (Low, <0.8 g/kg/d; Moderate; >0.8-1.2 g/kg/d; High >1.2 g/kg/d). The Primary outcome was clinically significant weight loss (CSWL, 5%). Secondary outcomes included anthropometry and measures of cardiovascular health. Results revealed that protein ingestion was: Low (n=278; 0.65 g/kg/d ± 0.12; range 0.24-0.80), Moderate (n=225; 0.98 g/kg/d ± 0.12; range 0.891-1.19) and High (142 (n=142; 1.66 g/kg/d ± 0.42; range 1.20-3.28). Weight change was: Gained weight (12%; 1.01 kg [0.24, 1.78]), exhibited non-CSWL (50%; -1.81 kg, [-2.04, -1.59]) and achieved CSWL (39%; -7.17 kg [-7.42, -6.92]). Post-hoc assessment showed that women in the high protein tertile did not gain a significant amount of weight (0.70 kg [-0.42, 1.81]) while those in the Low (0.97 kg [0.30, 1.64]) and Moderate protein tertiles (1.36 kg [0.84, 1.89]) gained weight. No other significant differences were observed for weight loss or lean body mass relative to protein tertiles. Interestingly, 57% of those consuming higher protein (1.66 ± 0.42 g/kg/d) achieved CSWL vs. ~33% in low (0.65 g/kg/d) and moderate protein (0.98 g/kg/d ± 0.12) groups (p=0.001). Further comparison demonstrated that Low protein consumers were significantly unlikely to achieve CSWL while those ingesting high protein were significantly more likely to achieve CSWL. We concluded that despite the lack of difference for magnitude of weight loss between protein groups, high protein consumers were significantly more likely to achieve CSWL during a short exercise intervention consisting of resistance and cardiovascular training. Equally, higher protein consumption may offset the magnitude of weight gain vs. lower protein intakes if weight loss is not achieved.

5. Behavioral Factors that Contribute Weight Loss and Maintenance

In addition to considering the impact of physical activity and diet on weight loss and maintenance, it is important consider behavioral factors that may affect weight loss success. Varkevisser et al. [47] recently published a meta-analysis on behavior factors that affect weight loss and maintenance. They found that 100% of studies reporting successful weight loss included not eating fast food or at restaurants; 87% involved cutting unhealthy food from the diet; 83% involved increasing fruit & vegetables in the diet; 80% incorporated weekly data reports that involve monitoring weight, not using meal replacements during weight loss and maintenance, reduction of energy intake and consumption of energy dense foods in the diet, or reducing sugar-sweetened beverages; 76% involved increasing physical activity; and, 75% involved self-monitoring of eating; portion control, or reducing fat intake. Our work supports these findings in that we have found that developing training and diet relationships and partners; increasing vegetables and fruits in the diet; spacing meals throughout the day; and, adding weekly counseling sessions, online diet and activity monitoring, and coaching feedback enhanced compliance and improved results [71, 72]. Thus, as one counsel's individuals about effective weight loss strategies, the practitioner should attempt to incorporate some of these behavioral interventions [73, 74].

6. Conclusions

Low to moderate intensity exercise provides significant health benefit but marginally affects weight loss in sedentary individuals initiating training. Diet intervention serves as the primary means of initially promoting weight loss in sedentary overweight or obese individuals but greater and more sustained effects are observed when combining diet and exercise [75]. Low to moderate intensity cardiovascular exercise has been the most common form of physical activity in weight loss studies. However, incorporating resistance-exercise during a weight loss intervention can be an effective way to promote fat loss without loss in fat-free mass or resting energy expenditure, particularly when adhering to a higher protein and low fat diet. This approach is likely safe and effective for healthy men and women, individuals at higher risk for chronic disease, elderly, and individuals with controlled medical conditions. Individuals initiating a diet and exercise program with metabolic syndrome or insulin resistance may experience greater benefit particularly in terms of reducing triglycerides and managing blood glucose. Additionally, maintaining a higher protein diet may help individuals achieve clinically significant weight loss and be more resistant to gaining weight. Maintaining physical activity after weight loss is a primary factor in preventing weight regain. Incorporating behavioral factors associated with weight loss or maintenance can improve outcomes. Finally, more work is needed to understand how genetics and/or gene expression influences outcomes as more personalize approaches are developed. These recommendations are consistent with the recently published International Society of Sports Nutrition position stand on diets and body composition [76]. It is recommended that individuals interested in optimizing body composition through training refer to this excellent review.

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References

1. Wilborn C, Beckham J, Campbell B, Harvey T, Galbreath M, La Bounty P, et al. Obesity: Prevalence, theories, medical consequences, management, and research directions. J Int Soc Sports Nutr. 2005; 2: 4-31.
2. Buch A, Carmeli E, Boker LK, Marcus Y, Shefer G, Kis O, et al. Muscle function and fat content in relation to sarcopenia, obesity and frailty of old age--an overview. Exp Gerontol. 2016; 76: 25-32.
3. McCullough PA, Fallahzadeh MK, Hegazi RM. Nutritional deficiencies and sarcopenia in heart failure: A therapeutic opportunity to reduce hospitalization and death. Rev Cardiovasc Med. 2016; 17: S30-S39.
4. Oh C, Jeon BH, Reid Storm SN, Jho S, No JK. The most effective factors to offset sarcopenia and obesity in the older Korean: Physical activity, vitamin D, and protein intake. Nutrition. 2017; 33: 169-173.

5. Ogden CL, Carroll MD, Lawman HG, Fryar CD, Kruszon-Moran D, Kit BK, et al. Trends in obesity prevalence among children and adolescents in the United States, 1988-1994 through 2013-2014. JAMA. 2016; 315: 2292-2299.
6. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999-2010. JAMA. 2012; 307: 491-497.
7. Flegal KM, Kruszon-Moran D, Carroll MD, Fryar CD, Ogden CL. Trends in obesity among adults in the United States, 2005 to 2014. JAMA. 2016; 315: 2284-2291.
8. Fakhouri TH, Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity among older adults in the United States, 2007-2010. NCHS Data Brief. 2012; 106: 1-8.
9. Bouchard C. Defining the genetic architecture of the predisposition to obesity: A challenging but not insurmountable task. Am J Clin Nutr. 2010; 91: 5-6.
10. Gardner KR, Sapienza C, Fisher JO. Genetic and epigenetic associations to obesity-related appetite phenotypes among African-American children. Pediatr Obes. 2015; 10: 476-482.
11. El Ghoch M, Calugi S, Dalle Grave R. Weight cycling in adults with severe obesity: A longitudinal study. Nutr Diet. 2018; 75: 256-262.
12. Swift DL, McGee JE, Earnest CP, Carlisle E, Nygard M, Johannsen NM. The effects of exercise and physical activity on weight loss and maintenance. Prog Cardiovasc Dis. 2018; 61: 206-213.
13. Coletta AM, Sanchez B, O'Connor A, Dalton R, Springer S, Koozehchian MS, et al. Alignment of diet prescription to genotype does not promote greater weight loss success in women with obesity participating in an exercise and weight loss program. Obes Sci Pract. 2018; 4: 554-574.
14. Guenard F, Houde A, Bouchard L, Tchernof A, Deshaies Y, Biron S, et al. Association of LIPA gene polymorphisms with obesity-related metabolic complications among severely obese patients. Obesity. 2012; 20: 2075-2082.
15. Heid IM, Huth C, Loos RJ, Kronenberg F, Adamkova V, Anand SS, et al. Meta-analysis of the INSIG2 association with obesity including 74,345 individuals: Does heterogeneity of estimates relate to study design? PLoS Genet. 2009; 5: e1000694.
16. Kilpelainen TO, Qi L, Brage S, Sharp SJ, Sonestedt E, Demerath E, et al. Physical activity attenuates the influence of FTO variants on obesity risk: A meta-analysis of 218,166 adults and 19,268 children. PLoS Med. 2011; 8: e1001116.
17. Kim JY, DeMenna JT, Puppala S, Chittoor G, Schneider J, Duggirala R, et al. Physical activity and FTO genotype by physical activity interactive influences on obesity. BMC Genet. 2016; 17: 1-7.
18. Gardner CD, Trepanowski JF, Del Gobbo LC, Hauser ME, Rigdon J, Ioannidis JP, et al. Effect of low-fat vs low-carbohydrate diet on 12-month weight loss in overweight adults and the association with genotype pattern or insulin secretion: The DIETFITS randomized clinical trial. JAMA. 2018; 319: 667-679.
19. Stanton MV, Robinson JL, Kirkpatrick SM, Farzinkhou S, Avery EC, Rigdon J, et al. DIETFITS study (diet intervention examining the factors interacting with treatment success) - study design and methods. Contemp Clin Trials. 2017; 53: 151-161.
20. Clifton PM, Keogh JB, Noakes M. Long-term effects of a high-protein weight-loss diet. Am J Clin Nutr. 2008; 87: 23-29.
21. Galbreath M, Campbell B, LaBounty P, Bunn J, Dove J, Harvey T, et al. Effects of adherence to a higher protein diet on weight loss, markers of health, and functional capacity in older women participating in a resistance-based exercise program. Nutrients. 2018; 10: 1070.

22. Maltais ML, Perreault K, Courchesne-Loyer A, Lagace JC, Barsalani R, Dionne IJ. Effect of resistance training and various sources of protein supplementation on body fat mass and metabolic profile in sarcopenic overweight older adult men: A pilot study. Int J Sport Nutr Exerc Metab. 2016; 26: 71-77.
23. Byrne NM, Meerkin JD, Laukkanen R, Ross R, Fogelholm M, Hills AP. Weight loss strategies for obese adults: Personalized weight management program vs. standard care. Obesity. 2006; 14: 1777-1788.
24. Goni L, Cuervo M, Milagro FI, Martinez JA. Future perspectives of personalized weight loss interventions based on nutrigenetic, epigenetic, and metagenomic data. J Nutr. 2016; 146: 905S-912S.
25. Donnelly JE, Blair SN, Jakicic JM, Manore MM, Rankin JW, Smith BK. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. Med Sci Sports Exerc. 2009; 41: 459-471.
26. Chin SH, Kahathuduwa CN, Binks M. Physical activity and obesity: What we know and what we need to know. Obes Rev. 2016; 17: 1226-1244.
27. Irwin ML, Yasui Y, Ulrich CM, Bowen D, Rudolph RE, Schwartz RS, et al. Effect of exercise on total and intra-abdominal body fat in postmenopausal women: A randomized controlled trial. JAMA. 2003; 289: 323-330.
28. Nishijima H, Satake K, Igarashi K, Morita N, Kanazawa N, Okita K. Effects of exercise in overweight Japanese with multiple cardiovascular risk factors. Med Sci Sports Exerc. 2007; 39: 926-933.
29. Alves JG, Gale CR, Mutrie N, Correia JB, Batty GD. A 6-month exercise intervention among inactive and overweight favela-residing women in Brazil: The caranguejo exercise trial. Am J Public Health. 2009; 99: 76-80.
30. Musto A, Jacobs K, Nash M, DelRossi G, Perry A. The effects of an incremental approach to 10,000 steps/day on metabolic syndrome components in sedentary overweight women. J Phys Act Health. 2010; 7: 737-745.
31. David P, Buckworth J, Pennell ML, Katz ML, DeGraffinreid CR, Paskett ED. A walking intervention for postmenopausal women using mobile phones and interactive voice response. J Telemed Telecare. 2012; 18: 20-25.
32. Willis LH, Slentz CA, Bateman LA, Shields AT, Piner LW, Bales CW, et al. Effects of aerobic and/or resistance training on body mass and fat mass in overweight or obese adults. J Appl Physiol. 2012; 113: 1831-1837.
33. Donnelly JE, Honas JJ, Smith BK, Mayo MS, Gibson CA, Sullivan DK, et al. Aerobic exercise alone results in clinically significant weight loss for men and women: Midwest exercise trial 2. Obesity. 2013; 21: E219-E228.
34. Kirk EP, Donnelly JE, Smith BK, Honas J, Lecheminant JD, Bailey BW, et al. Minimal resistance training improves daily energy expenditure and fat oxidation. Med Sci Sports Exerc. 2009; 41: 1122-1129.
35. Kerksick CM, Wilborn CD, Campbell BI, Roberts MD, Rasmussen CJ, Greenwood M, et al. Early-phase adaptations to a split-body, linear periodization resistance training program in college-aged and middle-aged men. J Strength Cond Res. 2009; 23: 962-971.
36. Moghadasi M, Mohammadi Domieh A. Effects of resistance versus endurance training on plasma lipocalin-2 in young men. Asian J Sports Med. 2014; 5: 108-114.

37. Roberts CK, Croymans DM, Aziz N, Butch AW, Lee CC. Resistance training increases SHBG in overweight/obese, young men. Metabolism. 2013; 62: 725-733.
38. Goodpaster BH, Delany JP, Otto AD, Kuller L, Vockley J, South-Paul JE, et al. Effects of diet and physical activity interventions on weight loss and cardiometabolic risk factors in severely obese adults: A randomized trial. JAMA. 2010; 304: 1795-1802.
39. Foster-Schubert KE, Alfano CM, Duggan CR, Xiao L, Campbell KL, Kong A, et al. Effect of diet and exercise, alone or combined, on weight and body composition in overweight-to-obese postmenopausal women. Obesity. 2012; 20: 1628-1638.
40. Baetge C, Earnest CP, Lockard B, Coletta AM, Galvan E, Rasmussen C, et al. Efficacy of a randomized trial examining commercial weight loss programs and exercise on metabolic syndrome in overweight and obese women. Appl Physiol Nutr Metab. 2017; 42: 216-227.
41. Kerksick C, Thomas A, Campbell B, Taylor L, Wilborn C, Marcello B, et al. Effects of a popular exercise and weight loss program on weight loss, body composition, energy expenditure and health in obese women. Nutr Metab. 2009; 6: 23.
42. Kerksick CM, Wismann-Bunn J, Fogt D, Thomas AR, Taylor L, Campbell BI, et al. Changes in weight loss, body composition and cardiovascular disease risk after altering macronutrient distributions during a regular exercise program in obese women. Nutr J. 2010; 9: 1-19.
43. Kreider RB, Rasmussen C, Kerksick CM, Wilborn C, Taylor L, Campbell B, et al. A carbohydrate-restricted diet during resistance training promotes more favorable changes in body composition and markers of health in obese women with and without insulin resistance. Phys Sportsmed. 2011; 39: 27-40.
44. Kreider RB, Serra M, Beavers KM, Moreillon J, Kresta JY, Byrd M, et al. A structured diet and exercise program promotes favorable changes in weight loss, body composition, and weight maintenance. J Am Diet Assoc. 2011; 111: 828-843.
45. Lockard B, Earnest CP, Oliver J, Goodenough C, Rasmussen C, Greenwood M, et al. Retrospective analysis of protein- and carbohydrate-focused diets combined with exercise on metabolic syndrome prevalence in overweight and obese women. Metab Syndr Relat Disord. 2016; 14: 228-237.
46. Muller MJ, Enderle J, Pourhassan M, Braun W, Eggeling B, Lagerpusch M, et al. Metabolic adaptation to caloric restriction and subsequent refeeding: The minnesota starvation experiment revisited. Am J Clin Nutr. 2015; 102: 807-819.
47. Varkevisser RD, van Stralen MM, Kroeze W, Ket JC, Steenhuis IH. Determinants of weight loss maintenance: A systematic review. Obes Rev. 2018; 20: 171-211.
48. Westerterp-Plantenga MS, Kempen KP, Saris WH. Determinants of weight maintenance in women after diet-induced weight reduction. Int J Obes Relat Metab Disord. 1998; 22: 1-6.
49. Turicchi J, O'Driscoll R, Finlayson G, Beaulieu K, Deighton K, Stubbs RJ. Associations between the rate, amount, and composition of weight loss as predictors of spontaneous weight regain in adults achieving clinically significant weight loss: A systematic review and meta-regression. Obes. Rev. 2019; 20: 935-946.
50. Stiegler P, Cunliffe A. The role of diet and exercise for the maintenance of fat-free mass and resting metabolic rate during weight loss. Sports Med. 2006; 36: 239-262.
51. Mateo-Gallego R, Marco-Benedi V, Perez-Calahorra S, Bea AM, Baila-Rueda L, Lamiquiz-Moneo I, et al. Energy-restricted, high-protein diets more effectively impact cardiometabolic profile in overweight and obese women than lower-protein diets. Clin Nutr. 2017; 36: 371-379.

52. Pesta DH, Samuel VT. A high-protein diet for reducing body fat: Mechanisms and possible caveats. Nutr Metab. 2014; 11: 1-8.
53. Heydari M, Freund J, Boutcher SH. The effect of high-intensity intermittent exercise on body composition of overweight young males. J Obes. 2012; 2012: 1-2.
54. Mears SA, Shirreffs SM. The effects of high-intensity intermittent exercise compared with continuous exercise on voluntary water ingestion. Int J Sport Nutr Exerc Metab. 2013; 23: 488-497.
55. Obert J, Pearlman M, Obert L, Chapin S. Popular weight loss strategies: A review of four weight loss techniques. Curr Gastroenterol Rep. 2017; 19: 61.
56. Trapp EG, Chisholm DJ, Freund J, Boutcher SH. The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women. Int J Obes. 2008; 32: 684-691.
57. Wilson RA, Deasy W, Stathis CG, Hayes A, Cooke MB. Intermittent fasting with or without exercise prevents weight gain and improves lipids in diet-induced obese mice. Nutrients. 2018; 10: 346.
58. Hunter GR, McCarthy JP, Bamman MM. Effects of resistance training on older adults. Sports Med. 2004; 34: 329-348.
59. Koopman R. Dietary protein and exercise training in ageing. Proc Nutr Soc. 2011; 70: 104-113.
60. Vargas S, Romance R, Petro JL, Bonilla DA, Galancho I, Espinar S, et al. Efficacy of ketogenic diet on body composition during resistance training in trained men: A randomized controlled trial. J Int Soc Sports Nutr. 2018; 15: 31.
61. Magrans-Courtney T, Wilborn C, Rasmussen C, Ferreira M, Greenwood L, Campbell B, et al. Effects of diet type and supplementation of glucosamine, chondroitin, and MSM on body composition, functional status, and markers of health in women with knee osteoarthritis initiating a resistance-based exercise and weight loss program. J Int Soc Sports Nutr. 2011; 8: 1-17.
62. Pourteymour Fard Tabrizi F, Abbasalizad Farhangi M, Vaezi M, Hemmati S. Changes of body composition and circulating neopterin, omentin-1, and chemerin in response to thylakoid-rich spinach extract with a hypocaloric diet in obese women with polycystic ovary syndrome: A randomized controlled trial. Phytother Res. 2020; 35: 2594-2606.
63. Sadeghian M, Hosseini SA, Zare Javid A, Ahmadi Angali K, Mashkournia A. Effect of fasting-mimicking diet or continuous energy restriction on weight loss, body composition, and appetite-regulating hormones among metabolically healthy women with obesity: A randomized controlled, parallel trial. Obes Surg. 2021; 31: 2030-2039.
64. Wali JA, Solon-Biet SM, Freire T, Brandon AE. Macronutrient determinants of obesity, insulin resistance and metabolic health. Biology. 2021; 10: 336.
65. Tricò D, Moriconi D, Berta R, Baldi S, Quinones-Galvan A, Guiducci L, et al. Effects of low-carbohydrate versus mediterranean diets on weight loss, glucose metabolism, insulin kinetics and β-Cell function in morbidly obese individuals. Nutrients. 2021; 13: 1345.
66. Bauer W, Adamska-Patruno E, Krasowska U, Moroz M, Fiedorczuk J, Czajkowski P, et al. Dietary macronutrient intake may influence the effects of TCF7L2 rs7901695 genetic variants on glucose homeostasis and obesity-related parameters: A cross-sectional population-based study. Nutrients. 2021; 13: 1936.

67. Wilson P. Physical activity and dietary determinants of weight loss success in the US general population. Am J Public Health. 2016; 106: 321-326.
68. Andrade-Mayorga O, Diaz E, Salazar LA. Effects of four lipid metabolism-related polymorphisms on body composition improvements after 12 weeks of high-intensity interval training and dietary energy restriction in overweight/obese adult women: A pilot study. Front Physiol. 2021; 12: 712787.
69. Mardock M, Lockard B, Oliver J, Byrd M, Simbo S, Jagim A, et al. Comparative effectiveness of two popular weight loss programs in women I: Body composition and resting energy expenditure. J Int Soc Sports Nutr. 2011; 8: 1-2.
70. Earnest C, Lockard B, Baetge C, Greenwood M, Kreider RB. Retrospective analysis of weight loss relative to protein intake during short-term exercise training in women. Med Sci Sports Exerc. 2017; 49: 987.
71. Dashti HS, Gómez-Abellán P, Qian J, Esteban A, Morales E, Scheer FA, et al. Late eating is associated with cardiometabolic risk traits, obesogenic behaviors, and impaired weight loss. Am J Clin Nutr. 2021; 113: 154-161.
72. Greiner B, Checketts J, Fishbeck K, Hartwell M. Clinical characteristics and lifestyle behaviors among individuals with arthritis: An analysis of 2017 behavioral risk factor surveillance system data. J Osteopath Med. 2021; 121: 113-119.
73. Aronne LJ, Hall KD, Jakicic JM, Leibel RL, Lowe MR, Rosenbaum M, et al. Describing the weight‐reduced state: Physiology, behavior, and interventions. Obesity. 2021; 29: S9-S24.
74. Sharafi M, Faghri P, Huedo-Medina TB, Duffy VB. A simple liking survey captures behaviors associated with weight loss in a worksite program among women at risk of type 2 diabetes. Nutrients. 2021; 13: 1338.
75. Flack KD, Hays HM, Moreland J, Long DE. Exercise for weight loss: Further evaluating energy compensation with exercise. Med Sci Sports Exerc. 2020; 52: 2466-2475.
76. Aragon AA, Schoenfeld BJ, Wildman R, Kleiner S, VanDusseldorp T, Taylor L, et al. International society of sports nutrition position stand: Diets and body composition. J Int Soc Sports Nutr. 2017; 14: 1-19.