Effects of a hypocaloric high-protein diet and resistance training on body composition, resting energy expenditure, fitness, and quality of life in an overweight adult population

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Voorwoord

Deze scriptie is geschreven in het kader van ons afstudeerproject van de opleiding Voeding en Diëtetiek aan de Hogeschool van Amsterdam. In deze scriptie worden de resultaten van de Welprex studie, een onderzoek naar de effecten van een hypocalorisch, eiwitverrijkt dieet, in combinatie met krachttraining bij volwassenen met overgewicht of obesitas beschreven en becommentarieerd. We hebben gekeken naar de effecten van deze interventie op lichaamssamenstelling, rustmetabolisme, fitheid en kwaliteit van leven. Het artikel zal ingestuurd worden naar een medisch tijdschrift, met als doel publicatie.

Dit onderzoek is opgezet door andere studenten, zij hebben de onderzoeksgroep geworven, individuele voedingsadviezen opgesteld, gesprekken gevoerd met de cliënten en metingen verricht. Toen voor de studenten het onderzoek -en dus ook de interventie voor de cliënten- na 9 weken was beëindigd, hebben wij het overgenomen. Wij waren verantwoordelijk voor de halfjaarlijkse nameting en het maandelijks programma "gewichtsbehoud" waarin de cliënten die daartoe geïnteresseerd waren deel konden nemen. De focus tijdens deze bijeenkomsten was gericht op inzicht krijgen in het eigen eetgedrag, delen van ervaringen en oplossingsgericht leren denken.

Wij willen de volgende mensen bedanken voor de begeleiding en medewerking tijdens onze afstudeerperiode. Allereerst Amely van Bavel, docentbegeleidster, dankzij haar hebben we deze opdracht kunnen uitvoeren. Wij danken haar voor haar heldere toelichting tijdens de gesprekken en de samenwerking die wij als zeer prettig hebben ervaren. Hanna Zijlstra, voor de begeleiding bij het praktische deel van ons afstudeerproject. Peter Weijs, tweede lezer, voor de begeleiding bij het insturen van het artikel. Daarnaast willen wij alle studenten bedanken die hebben bijgedragen aan dit onderzoek, zonder hen was de totstandkoming van deze scriptie onmogelijk geweest. In het bijzonder Ashley Senff en Doreen Koehler, waarmee wij de halfjaarlijkse nametingen hebben verricht en de groepsbijeenkomsten gehouden.

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Hanna van Houdt en Marloes Mulder

Abstract

Background: The incidence of obesity is increasing rapidly. Effective interventions for weight loss and prevention of weight regain on the long term are therefore essential. Both high protein (HP) diet and resistance training (RT) might help to facilitate loss of fat mass (FM), while preserving fat free mass (FFM).

Aim: To determine the effects of a hypocaloric HP diet and a 9 week RT program on body composition, resting energy expenditure, fitness and quality of life (QoL) in overweight adults on both short (9 weeks) and longer term (6 months).

Methods: 73 overweight adults were assigned to one of four hypocaloric study groups (2-by-2 factorial design): control, high-protein (HP) diet (27 energy% protein), resistance training (RT) or both (HPRT). Participants in RT groups performed a 9 week resistance-based program three times per week. After this intervention, monthly group sessions aimed at weight maintenance were organized for all groups. Measurements on body composition (air displacement plethysmography), fitness (Åstrand-test), resting energy expenditure (REE, indirect calorimetry) and QoL (SF-36) were performed at baseline, after 9 weeks, and after 6 months.

Results: The 9 week intervention program was completed by 35 of 73 subjects. 21 completed 6 month measurements. Mean BMI at baseline was 31.6 (SD 4.6) kg/m^2. After 9 weeks, RT resulted in a greater reduction in body fat percentage (-3.6 (SD 3.4) % fat, *P*=0.02), and increase in FFM (0.5 (SD 2.3) kg, *P*=0.04) compared to no-RT groups. In the HP groups, differences in body composition were not significant compared to no-HP groups: FM change was -3.0 (SD 3.8) % vs. -2.0 (SD 2.7) % (*P*= 0.38) and FFM change was 0.1 (SD 2.2) kg vs. -0.4 (SD 2.1) kg (*P*=0.53). Combining a HP diet with RT resulted in a significant increase (*P*=0.02) instead of decrease in FFM (+1.6 (SD 1.6) kg vs. control group –0.3 (SD 1.7) kg). Differences were not sustained after 6 months. There were no differences between intervention groups related to fitness and QoL.

Conclusion: This study showed that combining a HP diet and RT resulted in a significant increase instead of decrease in FFM. More research, with a larger sample-size, and extra focus on compliance is advised to provide evidence for longer-term effects.

Key words: overweight, weight loss, high-protein diet, resistance training, body composition, resting energy expenditure, fitness, quality of life

Content

1. Introduction

Overweight and obesity are serious public health concerns nowadays, because of their high prevalence and severe associated risks, like hypertension, type 2 diabetes, coronary heart disease and certain forms of cancer[1]. Therefore, effective interventions for weight loss and prevention of weight regain on the long term are essential. However, there is no consensus about which form of exercise and dietary intervention has the greatest potential to achieve and remain weight loss[2].

High protein (HP) diets are a popular dietary approach, and can lead to a greater loss of bodyweight and fat mass (FM)[3], and a better preservation of lean body mass (LBM), compared to regular diets[4]. The underlying mechanisms are multifactorial. An increased protein intake may reduce nitrogen losses associated with low energy diets, and maintain muscle protein synthesis during catabolic situations[5]. Positive outcomes related to bodyweight and FM are thought to be due to increased satiety, which is associated with lower energy intake[4], and an increased thermogenic response[6,7]. The improved body composition caused by a higher protein intake can improve weight maintenance on the long term, because preservation of LBM is accompanied by maintenance of resting energy expenditure (REE)[8].

REE is lower following weight loss (mostly due to a reduced LBM) and may play a role in weight regain[9]. Therefore, a strategy that can reduce the decrease in REE following weight loss is essential with respect to weight maintenance. Resistance training (RT) has been reported to be effective in reducing FM, and preserving or even increasing fat free mass (FFM), and strength fitness. The preservation of FFM leads to a maintenance of REE[10]. Thus, RT during weight loss may have a positive effect on weight maintenance by preserving muscle mass[11] and REE[10].

Demling *et al*. (2000) found that the combination of a hypocaloric diet, increased protein intake and RT resulted in a significant loss of FM and gain of lean mass compared to a hypocaloric diet alone[12]. In overweight and obese women, a HP diet was superior to a low-fat, high carbohydrate diet either alone or when combined with aerobic training or RT in promoting weight loss and nitrogen balance, improving body composition and risk factors associated with the Metabolic syndrome[13]. Layman *et al.* (2005) found that a protein rich diet combined with exercise additively improved body composition during weight loss[2].

Weiss *et al.* (2007) concluded that caloric restriction significantly decreased aerobic fitness. On the contrary, exercise-induced weight loss significantly increased maximal oxygen uptake ($V_{O2\ max}$)[14]. Hunter *et al*. (2008) found that RT during weight loss resulted in a preservation of strength fitness, aerobic training was successful in conserving $V_{O2\ max}$[10]. In another study, exercise resulted in improved cardiovascular fitness, but there were no differences between high- and low-protein groups[14].

Besides several risks mentioned above, quality of life (QoL) is negatively associated with obesity[15,16]. Positive changes in QoL as a result of weight loss are reported in several studies[17,18]. In a study of Kerksick *et al.* (2009) physical functioning, bodily pain, general health, vitality, and mental health improved significantly throughout an exercise program[19]. Martin *et al.* (2009) concluded that exercise-induced QoL improvements were dose dependent and independent of weight change[20].

Effects of combining a HP diet and RT on body composition, fitness and QoL has not been studied extensively. Therefore, the aim of this study is to examine the effects of a HP, hypocaloric diet in combination with a RT program on body composition, REE, fitness, and QoL in overweight and obese adults on both short (9 weeks) and longer term (6 months). We hypothesize that this intervention would preserve FFM and REE, and improve fitness and QoL.

2. Methods

2.1 Participants

In this study 73 overweight and obese participants (BMI $\geq$ 25 kg/m^2, age > 18 years) were recruited through flyers spread in three different districts of Amsterdam, close to the research centre. Exclusion criteria were diabetes with medication, renal failure, cardiovascular disease, exercise asthma, use of medication for asthma or other airway diseases, joint complaints, pregnancy and/or lactation, invalidity, thyroid gland diseases, or use of antidepressants for less than one year. All procedures involving human subjects were in accordance with the ethical standards of the institution. Written informed consent was obtained from all participants prior to participation.

2.2 Design

This 9 week trial had a 2 x 2 factorial design. Participants were randomly assigned to one of the four 9 week interventions: 1. regular hypocaloric diet (control group), 2. hypocaloric high-protein diet (HP group), 3. regular hypocaloric diet and resistance training (RT group), 4. hypocaloric high-protein diet and resistance training (HPRT group). Participants in all interventions received exercise advice according to National Guidelines[21]. The 9 week intervention was performed from February 2009 until May 2009. To analyze the effects of the HP diet and RT program on the four parameters body composition, REE, fitness and QoL, several measurements were performed. Measurements were carried out at baseline, and after 9 weeks of intervention. To investigate effects on the longer term, measurements were also performed after 6 months from baseline. After the 9 week intervention, monthly group sessions primarily for weight maintenance, with focus on sharing experiences and making healthy choices, were organized. All measurements were performed in the Nutritional Assessment Lab of the University of Applied Sciences Amsterdam, School of Sports and Nutrition, Department of Nutrition and Dietetics.

2.3 Interventions

Dietary treatment. All subjects received hypocaloric diets based on REE (measured by indirect calorimetry, VMax Encore) multiplied by physical activity level (PAL, estimated by a three-day activity record), minus 600 calories, according to CBO guidelines for diagnosis and treatment of obesity in children and adults[22]. The regular diet (control and RT) consisted of 17 energy % protein, in the HP groups (HP and HPRT), protein calories were 27% of total caloric intake. Estimated differences in protein intake between the regular and HP groups were 25 grams of protein per day. All diets were based on the national food based dietary guidelines from the Nutrition Center, the Netherlands[23]. Each participant received approximately six consults, with a total duration of four hours. The subjects were instructed to record their food and beverage intake in a three-day dietary food record (two week days, one weekend day) at baseline, after 9 weeks, and after 6 months, in order to register intake and check dietary compliance.

Exercise treatment. Exercise advice was given to subjects in all four groups, and consisted of 60-90 minutes daily moderate physical activity. Additionally, the RT groups (RT and HPRT) received an exercise program including RT. The program was developed as a circuit training program, combining aerobic warming up with RT and aerobic cooling down, for a total of 60 minutes per session. Subjects were requested to attend three sessions a week. During those sessions, average heart rates were at 60-80% of the Hfmax. Sessions were supervised by certified trainers. Compliance was checked by registration of attendance during the training sessions.

2.5 Measurements

Participants had not been physically active, and had fasted for more than three hours before all measurements were done. Maximal one hour prior to measurement, subjects were allowed to drink water. Additionally, participants were requested to use the lavatory just before measurements.

Body composition. Body weight, FM and FFM were assessed by using the BodPod system (Life Measurement Inc, Concord, CA). BodPod was calibrated before each measurement. Each subject was tested in a swimsuit and a swim cap. Thoracic gas volume was measured according to the procedures described in the manual. Fat percentage was determined using the Siri equation.

Resting energy expenditure. REE was measured by indirect calorimetry with an open circuit indirect calorimeter, using the ventilated hood method (Vmax Encore; Viasys Healthcare,

Houten, Netherlands). The system was calibrated for volume and with two standard gases every day before use. The subjects were lying on their back, and were awake. The measurements took 20 min, steady state periods were selected according to the procedures for the ventilated hood system. Oxygen consumption and carbon dioxide production were measured; REE was calculated by using the Weir formula.

Fitness. $V_{O2\ max}$ was estimated by the Åstrand test, a submaximal bicycle test. During this test, subjects pedalled on a cycle ergometer at a constant workload for seven minutes. Heart rate was measured every minute, determining a steady state heart rate (between 130-170). Heart rate, workload, age, and gender were used to estimate $V_{O2\ max}$[24].

Quality of life. To evaluate health related QoL, the validated short-form 36 questionnaire[25,26] was administered. The item scores are combined to provide scales assessing functional status across three dimensions, subdivided into eight variables; functional status (physical functioning, social functioning, role limitations due to physical problems, role limitations due to emotional problems), well-being (mental health, energy and vitality, pain), and overall health evaluation (general health perception). Additionally, the variable health change past year was assessed. Within each variable, items are summated and analysed. Scores are transformed to a 0% to 100% scale, higher scores correlating with better QoL rating. Additionally, mean scores of dimensions are calculated.

2.6 Statistical analysis

Statistical analysis was performed using SPSS 17. Analysis of subjects that completed baseline, 9 week, and 6 month measurements was performed. Additionally, intention to treat analyses were used, with last values carried forward. Comparisons of baseline characteristics were performed by one way ANOVA. A paired sample t-test was used to measure within group differences. A two-factor ANOVA was used to determine the effects of exercise versus no exercise and protein versus no-protein at 9 weeks and 6 months, and to determine the interaction effect between protein and exercise. An alpha of 0·05 was used to determine statistical significance.

3. Results

3.1 Participants

Initially, 73 subjects (18 men, 55 women) were assigned to one of four interventions. The 9 week intervention program was completed by 35 subjects, the measurements at 6 months were completed by 21 subjects. Most subjects dropped out because of personal circumstances. Baseline characteristics were similar among participants assigned to the four groups (table 1). Additionally, for participants that completed the 9 week intervention, no differences in baseline characteristics between the four groups exist. The groups consisted of eleven (control), seven (HP), ten (RT), and nine (HPRT) participants after the 9 week intervention subsequently.

Table 1. Baseline characteristics of participants assigned to different groups.

	Overall mean (*n* 73)		Control (*n* 19)		HP (*n* 18)		RT (*n* 19)		HPRT (*n* 17)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	40·2	13·2	42·0	15·4	41·2	11·4	37·8	14·1	39·9	12·1
Weight (kg)	89·1	16·8	88·5	17·0	92·6	15·6	82·8	13·3	93·3	20·0
BMI (kg/m2)	31·6	4·6	30·9	4·9	31·6	4·0	30·6	4·0	33·3	5·5
FM (%)	39·5	8·1	39·2	8·2	39·2	9·8	38·4	7·4	41·5	7·2
REE (kcal)	1821	353	1824	316	1916	320	1705	313	1812	452
VO2max (ml/kg/min)	31	10	33	10	32	12	31	9	28	8

3.2 Compliance to dietary advice and exercise program

At baseline, mean advised intake was 1821 (SD 380) kcal and 119 (SD 24) g protein for HP groups. In no-HP groups, 1841 (SD 392) kcal, and 91 (SD 25) g protein were prescribed. At baseline, HP groups showed a significantly higher protein intake (98 (SD 30) g vs. 83 (SD 18) g, $P = 0{\cdot}02$), and a higher total energy intake (2188 (SD 612) kcal versus 1923 (SD 435) kcal, $P = 0{\cdot}04$) than no-HP groups. Further, protein and energy intake did not differ between the groups. Table 2 lists the dietary characteristics estimated from the dietary food records at baseline, after 9 weeks, and after 6 months within groups compared to advised and baseline intake. Mean attendance to the exercise program was 1·4 (SD 0·8) times per week.

Table 2. Energy and protein intake within groups compared to advised and baseline intake.

	HP groups		no-HP groups	
	Mean	SD	Mean	SD
Energy intake (kcal)				
Baseline advised	1821	380	1840	392
Baseline	2188*†	612	1923	435
9-weeks advised	1599	224	2002	361
9-weeks	1621‡	568	1510†‡	314
6-months advised	1660	163	1598	230
6-months	1629	28	1467†‡	262
Protein intake (g)				
Baseline advised	119	23	91	25
Baseline	98*†	30	83	18
9-weeks advised	110	16	97	20
9-weeks	84†	32	74†	25
6-months advised	102	15	72	12
6-months	77†	13	56†‡	12
Protein intake (% of total energy)				
Baseline advised	26	2	20	3
Baseline	18†‡	5	18†‡	4
9-weeks advised	28	3	19	2
9-weeks	21†	5	20	5
6-months advised	24	1	18	1
6-months	19	3	15†	1

** Statistically significant difference of mean intake compared to no-HP groups.*
† Statistically significant difference of mean intake compared to advised intake.
‡ Statistically significant difference of mean intake compared to baseline intake.
HP-groups: baseline (n 27), 9-weeks (n 12), 6-months (n 2), no-HP groups: baseline (n 36), 9-weeks (n 12), 6-months (n 4).

3.3 Short term effects

Body composition

Table 3 shows differences in body composition within each intervention group between baseline and 9 weeks. In each intervention group, bodyweight decreases significantly during the 9 week intervention, with exception of the HP group. The same accounts for BMI (kg/m^2) and FM (kg and %). In the HPRT group, the FFM (kg) increased from baseline to post treatment, in contradiction to other intervention groups.

Table 3. Differences within groups (baseline-9 weeks).

	Control (*n* 10)		HP (*n* 8)		RT (*n* 10)		HPRT (*n* 8)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Weight (kg)								
Baseline	87·1	15·2	92·0	15·7	85·9	14·8	83·8	14·6
9-weeks	84·5	15·3	88·2	15·0	82·2	14·7	80·3	14·4
difference	- 2·6*	2·6	- 3·7	4·6	- 3·7***	2·1	- 3·5***	1·4
BMI (kg/m2)								
Baseline	30·1	4·3	32·0	4·4	29·9	3·5	31·2	4·7
9-weeks	29·2	4·5	30·7	4·5	28·6	3·6	30·2	4·9
difference	- 0·9**	0·8	- 1·2	1·5	- 1·3***	0·7	- 1·1**	0·8
FM (%)								
Baseline	38·3	9·5	39·4	12·4	34·5	7·6	41·0	6·1
9-weeks	36·8	9·9	38·4	12·4	32·0	8·5	36·1	8·7
difference	- 1·5*	1·9	- 1·0	3·6	- 2·5*	3·4	- 4·9**	3·1
FM (kg)								
Baseline	34·0	12·7	36·8	13·8	29·6	8·4	34·6	9·2
9-weeks	31·6	12·4	34·5	14·1	26·4	8·9	29·6	10·9
difference	- 2·3**	2·1	- 2·3	4·5	- 3·2**	3·1	- 5·1**	2·7
FFM (kg)								
Baseline	53·1	9·1	55·1	11·8	56·3	11·9	49·1	8·8
9-weeks	52·8	9·7	53·7	11·1	55·8	11·8	50·7	9·0
difference	- 0·3	1·7	- 1·4	1·7	- 0·4	2·5	1·6*	1·6

**P<0.05, **P<0.01, ***P<0.001.*

After 9 weeks of intervention, a greater reduction in percent FM was observed in the RT groups, compared to no-RT groups, P = .02. Figure 1 points out that the decrease in fat percentage was higher in the RT groups (3·6 (SD 3·4) %) than in the groups without RT (1·3 (SD 2·7) %). Additionally, there was a significant main effect for RT in change of FFM, P = .04. In RT groups, FFM increased 0·5 (SD 2·3) kg, compared to a decrease of 0·8 (SD 1·8) kg in the groups without RT. Although no significant results were found, participants with a mean attendance rate of more than 2·0 times per week showed better results. In this group, FM decreased 4·5 (SD 1·4) % and FFM increased 0·7 (SD 1·4) kg compared to participants with a lower attendances (3·1 (SD 1·0) % and 0.3 (SD 2.7) kg). In the HP groups, differences in body composition were not significant compared to no-HP groups. In figure 2 it is visible that there was a greater decrease in percent FM compared to no-HP groups (-3.0 (SD 3.8) % vs. -2.0 (SD 2.7) %, P= 0.38). FFM change was 0.1 (SD 2.2) kg vs. -0.4 (SD 2.1) kg for no-HP groups (P=0.53). The main effect of RT was qualified by the interaction between HP and RT, P = .02 (figure 3). This indicated that the combination of RT and a HP diet resulted in a more than additional effect on FFM (+1·6 (SD 1·6) kg).

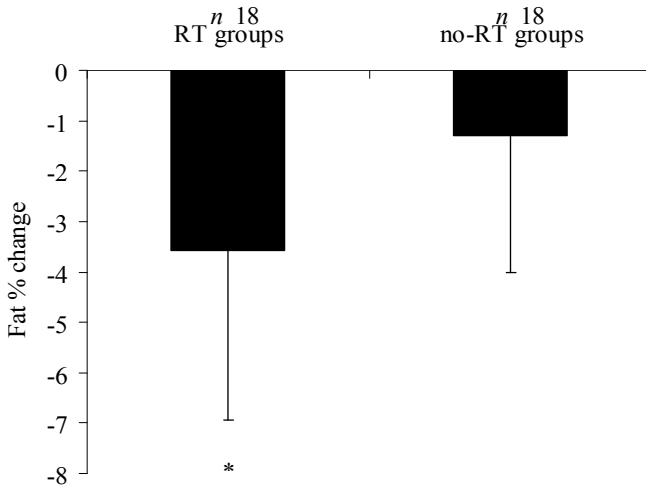

Fig. 1. Fat % change following the 9 week intervention (RT vs. no-RT). Values are means and standard errors of the mean. Column sharing the same symbol denote significant differences between groups: *P<0·05.

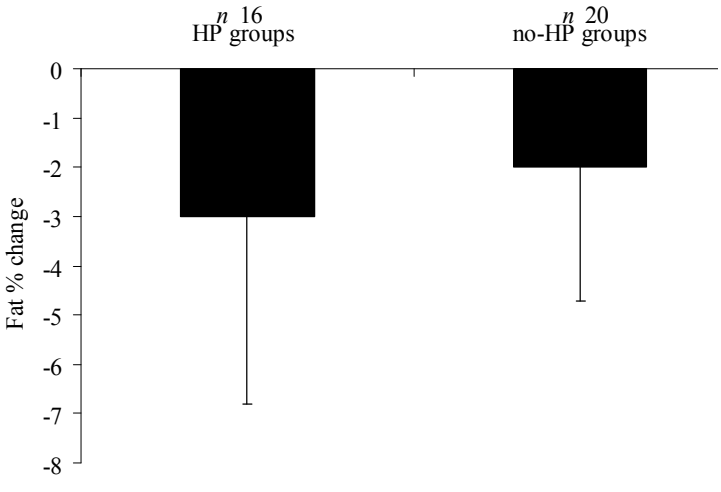

Fig. 2. Fat % change following the 9 week intervention (HP vs. no-HP). Values are means and standard errors of the mean.

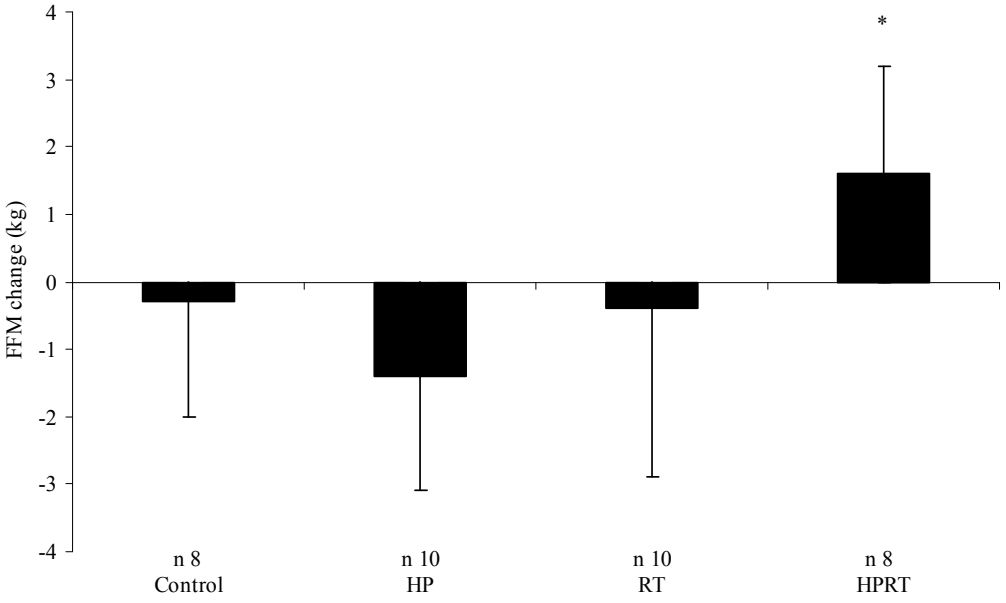

Fig. 3. FFM change (kg) following the 9 week intervention for the different groups. Values are means and standard errors of the mean. Column sharing the same symbol denote significant differences between groups: *P<0·05 compared to other groups.

Resting energy expenditure

Indirect calorimetry measurements were obtained to determine changes in REE. There were no differences within groups between baseline and 9 weeks. Furthermore, there were no significant changes in REE over the course of the study between the intervention groups. Even though no significant changes were found, RT seemed to preserve REE. Without RT, REE decreased during the 9 week intervention in contrary to the groups that did receive RT (-115·2 (SD 236·6) kcal vs. 14·8 (SD 138·7) kcal).

Fitness

There were no significant differences within the intervention groups. Additionally, no significant interaction effects were found between protein and exercise. However, $V_{O2\ max}$ (ml/kg/min) seemed to increase from baseline to post-treatment in the RT groups, compared to the intervention groups without RT, but changes were not significant. RT resulted in an increase in $V_{O2\ max}$ (ml/kg/min) of 5·3 (SD 8·4) ml/kg/min. Without RT, $V_{O2\ max}$ (ml/kg/min) increased 0·7 (SD 9·0) ml/kg/min.

Quality of life

There were no significant improvements within the intervention groups between baseline and 9 weeks. Individual QoL subscales were completed at baseline and after 9 weeks. In table 4 it is visible that differences between intervention groups for the total questionnaire were not significant. However, the dimension functional status improved significantly in RT groups (5·3 (SD 14·0), $P = 0.05$).

Table 4. Differences in QoL between exercise and no exercise groups (baseline-9 weeks).

	RT groups (*n* 17)		No-RT groups (*n* 17)	
	Mean	SD	Mean	SD
Overall score	5·6	12·7	- 1·0	13·5
Functional status	5·3*	14·0	- 6·8	19·6
Physical functioning	- 1·2	12·6	0·0	11·9
Social functioning	5·9	27·3	0·7	19·0
Role limititions physical	8·8	17·5	- 16·2	46·7
Role limititions emotional	7·8	25·1	- 11·8	33·2
Well-being	2·1	13·1	1·1	12·2
Mental health	7·8	21·3	- 1·4	11·7
Energy and vitality	6·8	19·0	6·2	12·6
Pain	- 8·2	20·2	- 1·6	24·9
Overall health evaluation	6·5	16·1	0·0	13·0
Genaral health perception	6·5	16·1	0·0	13·0
Health change past year	16·2	30·5	14·7	26·6

*$P<0.05$.

3.4 Longer term effects

After 6 months, the RT group showed a significant decrease in BMI (28·0 (SD 3·9) kg/m^2, vs. 29·4 (SD 3·9) kg/m^2, P = 0·04) compared to baseline. The HP group showed a significant increase in FFM during the course of the study (50·1 (SD 10·5) kg, vs. 49·1 (SD 9·8) kg, P = 0·03) (table 5). After 6 months, effects between the four intervention groups in body composition, REE, fitness and QoL were weakened (table 6). Differences between groups following the 9 week intervention; FFM (kg), fat percentage, and the dimension functional status of the SF-36 were not apparent on the longer term. After 6 months, the groups consisted of five (control), four (HP), seven (RT), and five (HPRT) participants subsequently.

Table 5. Differences within groups (baseline-6 months).

	Control (*n* 4)		HP (*n* 5)		RT (*n* 7)		HPRT (*n* 5)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Weight (kg)								
Baseline	77·2	9·4	87·6	14·3	85·3	15·2	89·5	21·8
6-months	72·3	5·2	82·3	11·2	81·5	14·8	88·8	25·6
difference	- 5·0	6·8	- 5·3	5·8	- 3·8	4·4	- 0·7	4·3
BMI (kg/m2)								
Baseline	27·7	2·8	31·1	4·3	29·4	3·9	32·6	6·6
6-months	25·3	0·8	29·4	4·1	28·0	3·9	32·3	7·8
difference	- 2·4	2·1	- 1·7	1·9	- 1·4*	1·4	- 0·3	1·5
FM (%)								
Baseline	35·1	10·5	43·6	8·9	35·4	9·0	43·6	7·2
6-months	31·6	4·7	38·7	12·1	33·3	9·7	42·3	10·8
difference	- 3·5	6·5	- 4·9	5·0	- 2·1	4·1	- 1·3	4·0
FM (kg)								
Baseline	27·7	11·7	38·6	11·4	30·2	9·9	40·0	15·3
6-months	22·8	3·6	32·2	12·7	27·2	10·5	39·4	19·8
difference	- 4·9	8·1	- 6·3	6·2	- 3·0	4·9	- 0·6	4·8
FFM (kg)								
Baseline	49·5	5·0	49·1	9·8	55·1	12·3	49·5	7·7
6-months	49·5	5·4	50·1	10·5	54·0	11·9	49·4	7·5
difference	- 0·1	2·3	1·1*	0·7	- 1·1	2·3	- 0·1	1·5

*$P<0.05$.

Table 6. Differences between groups (baseline-6 months).

	Overall mean (*n 21*)		Control (*n* 4)		HP (*n* 5)		RT (*n* 7)		HPRT (*n* 5)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Weight (kg)	- 3·6	5·8	- 4·6	6·8	- 5·3	5·8	- 3·8	4·4	- 0·7	4·3
FM (kg)	- 3·6	5·8	- 4·9	8·1	- 6·3	6·2	- 3·0	4·9	- 0·6	4·8
FM (%)	- 2·9	4·6	- 3·5	6·5	- 4·9	5·0	- 2·1	4·1	- 1·3	4·0
FFM (kg)	- 0·1	1·9	- 0·1	2·3	1·1	0·7	- 1·1	2·3	- 0·1	1·5
REE (kcal)	- 14	194	- 72	380	- 84	105	12	151	61	188
VO2max (ml/kg/min)	4	10	- 2	7	8	6	7	13	- 5	4
QOL (total score)	2·5	11·5	- 3·9	2·9	- 1·0	12·5	7·7	4·7	1·0	19·1

3.5 Intention to treat

According to the intention to treat analysis (last values carried forward), there was a significant interaction between HP and RT in change of FFM (kg), $P = 0{\cdot}03$. In addition, fat percentage decreased significantly in RT groups, $P = 0{\cdot}05$. Additionally, RT groups scored significantly higher on the variable role limitations due to physical problems ($P = 0{\cdot}05$). Thus, significant effects were also found when intention to treat analyses were used as a replacement for analysis that excluded missing data (after 9 weeks).

4. Discussion

The purpose of this study was to determine the effects of a hypocaloric HP diet in combination with a RT program on body composition, REE, fitness, and QoL in overweight and obese adults on both short and longer term.

Our hypothesis was that a hypocaloric, HP diet in combination with a RT program would preserve FFM and REE, and improve fitness and QoL. Results from this study partly confirm this hypothesis. The combination of a HP intake and RT lead to a more than additive increase in FFM compared to RT alone. This finding accords with results of previous studies that investigated the interaction of a HP diet with exercise, in overweight and obese adults. A hypocaloric diet with increased protein intake and RT resulted in a significant loss of FM and gain of LBM, probably due to increased nitrogen retention[12]. Layman *et al.* (2005) found that the combined effects of a HP diet and exercise on body composition appeared to be additive. In this study, exercise treatment consisted of five days per week walking and two days per week RT. The group with a HP diet and exercise lost most total weight and FM and tended to have the best preservation of LBM compared to the other groups. Fundamental mechanisms were not evaluated in this study, but the combined effects appear to be independent and additive for improving body composition[2]. In another study, it was concluded that a HP diet combined with a moderate-intensity training protocol (aerobic- and RT) is more effective in achieving short-term weight loss in overweight and obese women than a low-fat, high-carbohydrate diet[13]. Kerksick *et al.* (2009) concluded that combining a hypocaloric diet with RT resulted in positive outcomes related to body composition. Although not significant, greater improvements occurred when carbohydrate was replaced in the diet by protein[19].

In the present study, it is expected that protein may be an important factor for the maintenance of FFM induced by resistance training. Leidy *et al.* (2007) confirmed that HP diets lead to better preservation of LBM compared with regular diets[4], this is probably due to protein sparing effects of increased protein intake on LBM[5]. HP diets can also lead to a greater loss of bodyweight and FM[3]. Explanations for these beneficial outcomes as a result of HP intake are multifactorial. Initially, protein may promote satiety, which in turn can lower energy intake[4,27]. Increased protein levels also contribute to a higher thermogenic effect[7] compared to other macronutrients[6,28]. The absence of a main effect of extra protein on body composition at 9

weeks is not consistent with previous studies, and is probably due to the limited number of participants in that specific group. A few participants reported high satiety and an inability to consume more protein-rich foods, and therefore dropped-out. Protein intake was significantly lower than advised in the HP groups. However, there were significant differences between regular diet groups and HP groups regarding intake of protein (g) at baseline. On the other hand, when expressed as percentage of energy intake from protein, no significant differences persisted between the groups. This was due to the higher total energy intake in HP groups. In the present study, differences in protein intake between intervention groups were minor, when compared to other studies[4,8,29]. At 6 months, there was a significant main effect of HP on FFM (kg). However, this was probably caused by the fact that the remaining subjects adhered to the intervention most strictly, and therefore achieved the best results with respect to body composition.

Additionally, RT resulted in a greater reduction in percent FM and an increase in FFM. This indicates that exposure to RT ensures a greater loss of FM with reference to groups without RT. These findings are confirmed by previous studies, in which RT lead to a maintenance of or increase in LBM[2,10] and decrease in FM[2]. Furthermore, the dimension functional status (SF-36) was rated more positively in exercising participants. Positive changes in QoL as a result of RT are also reported in other studies[19], these exercise-induced QoL improvements were dose dependent and independent of weight change[20]. Attendance to the exercise program was 1·4 times per week where attendance of three sessions a week was requested. It is interesting that despite not reaching this attendance rate, the RT groups reached a greater reduction in percent FM, increase in FFM, and the dimension functional status (QoL). Participants with higher attendance rates showed better results, although not significant.

Despite the absence of a significant effect, RT resulted in an increase in $V_{O2\ max}$. This is in accordance with results from an earlier study in which only the RT groups had improved fitness[13]. Additionally, RT seems to maintain REE in this study. A possible explanation for this tendency is that RT leads to a better preservation of FFM in the present study. Preservation of FFM can maintain REE[8]. On the contrary, in groups without RT, REE decreased slightly. This is confirmed by a study of Hunter *et al.* (2008), in which better preservation of REE in groups with RT was found[10]. This is a relevant finding, since the maintenance of REE seems to prevent

weight regain on the long term[9]. REE is the largest component of total energy expenditure; consequently, influencing this factor can be important in weight management[30,31].

Differences within and between the intervention groups that were found after the 9 week intervention (compared to baseline) were not present after 6 months. However, there were no differences within groups between 9 weeks and 6 months. Probably, this lack of detection on the longer term is due to the low number of participants that completed the measurements at 6 months. Furthermore, finishing the RT program after 9 weeks could be responsible for the absence of effects after 6 months.

A strength of this study is that data from subjects who were noncompliant with the intervention protocols were not excluded from analysis. Consequently, the data reflect a more realistic situation, instead of the best-case scenario. A weakness of this study is the limited number of participants at the end of the study. As a result, differences on the longer term were not detected, despite the design of this study. Compared to other studies [4,12,13], this study had a high drop-out rate (48%). Personal circumstances was the most frequent reason for drop-out. The large time commitment was a further common complaint. Additionally, as mentioned before, participants in the HP groups reported high satiety and an inability to consume more protein-rich foods, and therefore dropped-out.

In conclusion, this study indicates that combining a hypocaloric, HP diet with RT resulted in a significant increase instead of decrease in FFM. These findings suggest that protein may be an important factor for the maintenance of FFM induced by RT. RT resulted in a greater reduction in percent FM and an increase in FFM. Furthermore, RT seemed to increase REE and $V_{O2\ max}$. Additionally, a dimension of QoL was rated more positively. Differences following the 9 week intervention were not apparent on the longer term, due to a low power after 6 months. Thus, the results of this study suggest that the combination of a HP diet and RT may be beneficial in maintaining FFM on the short term. However, more research, with a larger sample size, and extra focus on compliance is advised to provide further evidence for recommending a hypocaloric, HP diet in combination with RT as an intervention to accomplish favourable changes in body composition, fitness, and QoL on the longer term.

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