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Soy protein based supplementation supports metabolic effects of resistance training in previously untrained middle aged males

PETER DEIBERT[1], FLORIAN SOLLEDER[2], DANIEL KÖNIG[1], MARA Z. VITOLINS[3], HANS-HERMANN DICKHUTH[1], ALBERT GOLLHOFER[2], & ALOYS BERG[1]

[1]*Department of Rehabilitative and Preventive Sports Medicine, University Hospital, Freiburg, Germany,* [2]*Institute of Sports and Sports Science, Freiburg University, Freiburg, Germany and* [3]*Wake Forest University School of Medicine, Winston Salem, North Carolina, USA*

Abstract

Objective. To determine changes in body composition, physical performance, metabolic and hormonal parameters induced by lifestyle counselling, resistance training and resistance training with soy protein based supplemention in middle aged males.

Design. Randomised controlled study consisting of resistance training without (RT-G) or with (RTS-G) a soy protein based supplement and a control group with lifestyle education only (LE-G).

Subjects. Forty healthy middle aged men (50–65 years, BMI 25–29.9 kg/m^2).

Measurements. Changes in body weight (BW) and waist circumference (WC) were measured and body composition (BC), fat mass (FM), lean body mass (LBM) were measured by skin fold anthropometry at baseline and after 12 weeks of intervention. In addition, changes in physical fitness, metabolic and hormonal parameters (lipids, glucose, fructosamines, insulin, insulin-like growth factor-1, Leptin, human growth hormone, dehydroepiandrosterone, testosterone, hs-CRP, Il-6) were evaluated.

Results. Thirty-five participants completed the 12 week study. No significant changes in BW were noted although RM and WC dropped and LBM increased after training, particularly in the RTS group (FM 22.6 $\pm$ 5.5 kg to 21.2 $\pm$ 4.7 kg; LBM 68.5 $\pm$ 7.2 kg to 70.1 $\pm$ 7.4; $p < 0.01$). Subjects in the RTS group experienced more pronounced improvements in the strength measurements than the RT group. After the training intervention there were significant changes in hormonal and metabolic parameters as well as in glycemic control, particularly in the RTS group.

Conclusions. Our data suggest that resistance training, particularly in combination with a soy protein based supplement improves body composition and metabolic function in middle aged untrained and moderately overweight males.

Keywords: *Soy protein, resistance training, physical exercise, supplementation*

Introduction

There is an ongoing obesity epidemic in high income and developed countries due to decreased physical activity and increased caloric consumption; this has lead to an increased incidence of metabolic diseases, such as metabolic syndrome and type 2 diabetes mellitus [1,2]. To address this epidemic, lifestyle management has been recommended by leading research and medical organisations [3–5]. It is well documented that resistance training improves body composition and glycemic control [6–9]. Unfortunately, middle aged males often reject intervention strategies as unpractical and do not successfully follow them. Furthermore, most of the studies included people over 60 years of age or participants with concomitant diseases [10–16].

Another area that is understudied is whether the balance of macronutrients in the diet can improve body composition and metabolic control. It has been shown that protein rich diets may increase thermogenesis, spare muscle protein loss and improve glycemic control [17–21]. Pre- or post-exercise ingestion of protein or essential amino acids can increase muscular protein synthesis and result in a positive net protein balance [22–25]. Furthermore, the majority of studies in humans suggest that protein or essential amino acid ingestion in the context of a resistance training session can enhance skeletal muscle hypertrophy in response to chronic resistance training [26]. The most intensively studied protein sources used in training studies are whey and soy. We investigated the use of a protein supplement that is commercially available and contains soy and milk protein in a ratio of 4.8:1. In a 12 week

Correspondence: Prof. Dr. Aloys Berg, University Hospital, Department of Rehabilitative and Preventive Sports Medicine, Hugstetter Str. 55, D-79106 Freiburg, Germany. Tel: +49-761-270-7453. Fax: + 49-761-270-7470. E-mail: aloys.berg@klinikum.uni-freiburg.de

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randomised, controlled trial, we evaluated the efficacy of a resistance training programme in combination with the protein supplement in previously untrained and moderately overweight middle aged males.

The primary objectives of this study were to evaluate changes in body composition and improvement of metabolic and glycemic control; secondary objectives were to investigate the regulation of sex hormones, the change in muscular strength and inflammatory biomarkers.

Methods

Out of a group of more than 100 interested men who were recruited by the Department of Sports Medicine, Rehabilitation and Prevention of the Freiburg University Hospital, 40 male healthy subjects were enrolled in the study. All subjects had to be 50–65 years of age, have a BMI of 25.0–29.9 kg/m^2 and participated in less than 60 min per week of physical exercise in their leisure time at baseline (Table I). All participants performed a cycling test on an electrically braked cycle ergometer (Ergometrics 900; Ergoline, Windhagen, Germany) to the point of exhaustion. Heart rate was continuously monitored via an electrocardiogram, with blood pressure measured in the final minute of each work level. Exercise began with a workload of 50 W and was increased stepwise by 25 W every 2 min until exhaustion. At least 1 W/kg body weight had to be performed symptom-free. Exclusion criteria included having a significant illness, especially compromising the ability to be physically active, diabetes mellitus (1 and 2), taking lipid lowering medication or any drugs that could affect body weight.

Before starting the study, subjects completed a training history, had a comprehensive medical examination (including exercise electrocardiogram) and blood tests (blood count, creatinin, transaminases, glucose, protein electrophoresis, erythrocyte sedimentation rate, and thyroidea stimulating hormone).

Skinfolds (tricep, supraillium, abdomen and thigh) were measured with Lange skinfold callipers (Cambridge Scientific Industries, Inc., Cambridge, Maryland). All skinfolds were measured by the same investigator utilising the same caliper. Measures were taken in triplicate with a 2 mm reliability range. Final skinfolds were taken without viewing initial measures to minimise bias. Percent body fat was then estimated using the 4-site formula from the ACSM's Resource Manual for Guidelines for Testing and Prescription [27]. BMI was calculated as body mass in kilograms divided by height in meters squared (kg/m^2). Waist and hip circumferences were measured using a Gulick measuring tape with a calibrated tension device.

Written informed consent was provided by all subjects, and the study protocol was approved by the ethic board of the medical faculty of Freiburg University.

The subjects were randomly assigned to three different study arms: lifestyle education control group ($n = 10$, LE-G), resistance training group ($n = 15$, RT-G) and resistance training with supplementation (n 15, RTS-G). All participants attended two education sessions and two individual training and educational sessions, immediately before enrollment and 4 weeks of intervention. The nutritional consulting was conducted by a dietician trained in sports nutrition and followed the guidelines of the the 'German Society of Nutrition'. The resistance training counselling was provided by an interventionist experienced in providing training schedules and planning individual workouts. All subjects received a handout regarding diet and lifestyle developed from recommendations provided by the 'German Society of Nutrition' and the 'German Society of Sports Medicine and Prevention'. Participants were given recommendations to consume a moderate-fat, isocaloric balanced diet with 55% calories from carbohydrate, 30% from fat and 15% from protein throughout the study period. Additionally, subjects assigned to the RTS-G were instructed to consume 50 g of a commercially available soy–yogurt–honey that contained 26.7 g protein (Almased®, Table II) throughout the 12 weeks of intervention. They were instructed to consume it in

Table II. Supplement composition per 100 g.

Kilocalories	230
Protein (g)	26.7
Carbohydrates (g)	15.3
Fat (g)	7.0
Saturated fatty acids (g)	0.5
Fibres (g)	0.2
Calcium (mg)	217
Magnesium (mg)	45
Biotin (μg)	12
Folic acid (μg)	106

Composition of the used supplement consisting of a soy protein-yogurt-honey preparation, provided by Almased Corp., Bienenbüttel, Germany.

Table I. Demographic and anthropometric data at baseline.

Group	Age (yrs), M ± SD	Height (m), M ± SD	BW (kg), M ± SD	BMI (kg/m^2), M ± SD	WC (cm), M ± SD	FM (kg), M ± SD
Control ($n = 9$)	55.8 ± 5.5	1.74 ± 0.06	83.1 ± 8.7	27.2 ± 1.7	96.0 ± 5.6	20.5 ± 3.4
Training ($n = 26$)	55.7 ± 4.1	1.78 ± 0.06	89.8 ± 9.4	28.0 ± 2.3	97.9 ± 7.2	21.9 ± 5.1
RT ($n = 13$)	55.5 ± 4.8	1.79 ± 0.04	88.4 ± 7.1	27.7 ± 2.3	97.8 ± 6.7	21.1 ± 4.8
RTS ($n = 13$)	55.9 ± 3.5	1.78 ± 0.08	91.2 ± 11.4	28.4 ± 2.2	98.0 ± 8.0	22.6 ± 5.5

Data are shown as mean ± standard deviation. Both groups with resistance training were summarised as Training group.RTS group: resistance training with soy protein supplementation, RT-group: resistance training only, BW: body weight, WC: waist circumference, FM: fat mass.

Table III. Anthropometric data.

Group	*n*		Bodyweight (kg)	BMI (kg/m^2)	Waist circumference (cm)	Fat mass (kg)	Fatfree mass (kg)
Control group	9	Pre	83.1 ± 8.7	27.2 ± 1.7	96.0 ± 5.6	20.5 ± 3.4	62.7 ± 7.8
		Post	83.1 ± 9.3	27.3 ± 1.9	94.6 ± 6.4	19.6 ± 3.6	63.5 ± 7.5
Training group	26	Pre	89.8 ± 9.4	28.0 ± 2.3	97.9 ± 7.2	21.9 ± 5.1	67.9 ± 5.8
		Post	89.8 ± 8.5	28.1 ± 2.2	96.7 ± 6.3*	20.7 ± 4.5**	69.1 ± 5.7**
RT-group	13	Pre	88.4 ± 7.1	27.7 ± 2.3	97.8 ± 6.7	21.1 ± 4.8	67.3 ± 4.1
		Post	88.3 ± 6.0	27.7 ± 2.3	96.8 ± 6.2	20.2 ± 4.5	68.1 ± 3.4
RTS-group	13	Pre	91.2 ± 11.4	28.5 ± 2.2	98.0 ± 8.0	22.6 ± 5.5	68.5 ± 7.2
		Post	91.3 ± 10.5	28.5 ± 2.1	96.7 ± 6.6*	21.2 ± 4.7*	70.1 ± 7.4**

Data are shown as mean ± standard deviation, Pre = baseline data, Post = at the end of the 12 weeks intervention. Both groups with resistance training were summarized as a Training group RTS group:resistance training with soy protein supplementation.
RT-group: resistance training only. BMI: body mass index.
*$p < 0.05$, **$p < 0.01$ for intraindividual changes.

the evening between 6 and 7 p.m. or immediately after their evening training session to increase the compliance. In addition, supplement intake was documented by the participants in the training protocols.

The RT-G and the RTS-G followed a structured resistance training programme and were not restricted from doing other sports during the intervention. The resistance training was performed on fitness equipment (pull down, leg press, bench press, back press, etc.) and was conducted twice a week in 90 min sessions. Individual adaptations of the training protocol were made to the participant's performance on a week basis. The intensity was based on the number of possible repetitions (1.–4. week: 25 repetitions, 5.–9. week: 15 repetitions, 10.–12. week: 10 repetitions; 4 seconds per repetition) that lead to local muscular exertion and exhaustion. The training programme was overseen by one interventionist who took measurements of the 1 repetition maximum. Repetitions and amount of weight lifted was documented for each piece of training equipment to control and support the progression of the strength training.

Data collected at baseline and after 12 weeks (overnight fasting state in the morning) included body weight, waist circumference, blood pressure, glucose, insulin, fructosamine (glycated serum proteins), serum lipids and inflammatory markers (fibrinogen, IL-6, hs-CRP), leptin, free testosterone, dehydroepiandrosterone (DHEA), insulin-like growth factor-1 (IGF-1) and human growth hormone (HGH). Muscular performance was tested by standardised strength tests and total body coordination was measured by a one-leg stabilisation test [28]. Baseline dietary and physical activity compliance was estimated by self-reported records.

A placebo as a viscous drink containing fibres or carbohydrates as starch would have discrete effects itself. Therefore, we decided to abandon the use of a placebo.

Statistical methods

Testing for changes between examination at baseline and after intervention was done by paired sample *t* test. Normality of all variables was tested before statistical testing. Leptin, insulin and HGH values were normalised by logarithmic transformation for statistical testing. All *p*-values were two-sided and a *p*-value of 0.05 or less was considered to indicate statistical significance. The data were interpreted as per-protocol analysis, as the main focus was the impact of the intervention, not feasibility. Analysis was conducted with the use of SPSS software (version 11.5.2.1).

Results

Thirty-five of the 40 included participants completed the 12 weeks intervention. The five participants gave the following reasons for dropping out: did not like the study arm he was randomized to ($n = 1$), medical reasons ($n = 2$) and personal reasons ($n = 2$).

Demographic and anthropometric data of the total sample ($n = 35$) and the three intervention groups are given in Table I. No significant differences were noted among the groups. Data of participants who dropped-out ($n = 5$) did not differ from participants who completed the study.

Pre- and post-intervention data for the anthropometric variables are given in Table III. The resistance training groups (with and without supplementation) were merged to one group we titled 'training group'. The data of each group are shown. Despite finding no change in total body mass, resistance training led to significant improvements in fat free mass (pre- *vs.* post-training: 21.9 ± 5.1 *vs.* 20.7 ± 4.5 kg; $p < 0.01$) accompanied by significant reductions in waist circumference (97.9 ± 7.9 *vs.* 96.7 ± 6.3 cm; $p < 0.05$) and fat mass (21.9 ± 5.1 *vs.* 20.7 ± 4.5 cm; $p < 0.01$); the training induced changes in body composition were more pronounced in the RTS group. In the LE-G body composition remained unchanged.

Self-reported physical activity in the RT and RTS groups revealed approximately 90% compliance to attending training sessions. In contrast, the LE-G participants did not increase their physical activity during the study period. In addition, there were no significant changes in macronutrient composition of the diet in the LE-G and the RTG. In the supplemented

participants, protein consumption rose 23% which was a statistically significant change ($p < 0.05$).

The pre and post test results of the muscle strength and coordination tests are provided in Table IV. Compared to the LE-G, the resistance training led to significant improvements in isometric strength of low back extensor (+31% *vs.* +1%, $p < 0.001$) and flexor muscles (+17% *vs.* 0%; $p < 0.001$); the changes in muscular strength were more pronounced in the RTS group than the RT group. In addition, total body coordination was also significantly improved after resistance training as shown by the one-leg stabilisation test.

Data of anabolic hormones are given in Table V. In contrast to free testosterone and DHEA, resistance training in the RT and RTS induced significant increases in IGF-1 (+7%; $p < 0.05$) and HGH concentrations (+104%, $p < 0.01$) compared to the LE-G, in which no significant changes were demonstrated. Participants of the RTS group who started with a low HGH level showed a more pronounced HGH increase.

Variables expressing the metabolic risk and the incidence of the metabolic syndrome are given in Table VI. Resistance training for both groups induced significant improvements in glycemic control (fasting blood glucose: −5%, insulin: −23%, HOMA index:

Table IV. Power- and coordination data.

Group	*n*		Power test ext. (Nm)	Power test flex. (Nm)	Coordination test (mm)
Control group	9	Pre	181.4 ± 41.8	143.6 ± 25.6	1146.6 ± 483.2
		Post	183.4 ± 39.7	146.8 ± 28.1	1089.2 ± 346.3
Training group	26	Pre	178.9 ± 58.4	152.2 ± 37.3	1449.9 ± 967.9
		Post	234.7 ± 55.2***	178.0 ± 37.7***	771.3 ± 406.6***
RT-group	13	Pre	190.3 ± 53.7	144.2 ± 26.0	1469.5 ± 826.0
		Post	241.7 ± 51.8**	167.4 ± 25.7**	789.3 ± 470.2***
RTS-group	13	Pre	167.5 ± 62.7	160.2 ± 45.7	1430.3 ± 1126.3
		Post	227.8 ± 59.6***	188.5 ± 45.3***	753.2 ± 350.2*

Data are shown as mean ± standard deviation, Pre = baseline data, Post = at the end of the 12 weeks intervention. Both groups with resistance training were summarized as a Training group RTS group:resistance training with soy protein supplementation.
RT-group: resistance training only.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ for intraindividual changes.

Table V. Hormonal data.

Group	*n*		IGF-1 (ng/ml)	HGH (ng/ml)	f-Test (pg/ml)	DHEA (μg/l)
Control group	9	Pre	248.8 ± 59.9	0.28 ± 0.20	8.72 ± 4.28	8.19 ± 4.08
		Post	257.2 ± 60.1	0.23 ± 0.34	10.27 ± 4.77	9.20 ± 4.40
Training group	26	Pre	225.6 ± 70.8	0.25 ± 0.49	6.38 ± 4.56	9.25 ± 4.11
		Post	241.5 ± 76.2*	0.56 ± 0.67**	7.07 ± 4.66	9.43 ± 4.47
RT-group	13	Pre	206.1 ± 65.2	0.39 ± 0.66	5.73 ± 3.95	8.43 ± 2.81
		Post	222.4 ± 62.5	0.69 ± 0.77	6.79 ± 4.15	9.63 ± 3.65
RTS-group	13	Pre	245.2 ± 73.3	0.11 ± 0.14	7.03 ± 5.44	10.07 ± 5.08
		Post	260.6 ± 86.1	0.43 ± 0.55*	7.36 ± 5.28	9.23 ± 5.38

Data are shown as mean ± standard deviation, Pre = baseline data, Post = at the end of the 12 weeks intervention. Both groups with resistance training were summarized as a Training group RTS group:resistance training with soy protein supplementation.
RT-group: resistance training only; IGF: insuline growth factor; HGH: human growth hormone; f-Test: free testosterone; DHEA: dehydroepiandrosterone.
*$p < 0.05$ for intraindividual changes.

Table VI. Metabolic data.

Group	*n*		HDL-C (mg/dl)	Triglycerides (mg/dl)	Glucose (mg/dl)	Insulin (μU/ml)	HOMA-Index	Fructosamine (μmol/l)
Control group	9	Pre	56.4 ± 12.0	152.7 ± 43.5	87.1 ± 6.2	10.0 ± 7.3	2.2 ± 1.5	234.8 ± 21.5
		Post	60.0 ± 9.4	133.3 ± 50.7	90.3 ± 9.0	10.1 ± 5.2	2.3 ± 1.2	233.9 ± 17.6
Training group	26	Pre	49.7 ± 15.5	205.4 ± 169.6	98.0 ± 15.7	12.9 ± 11.0	3.2 ± 2.9	236.1 ± 17.1
		Post	53.9 ± 17.7*	150.8 ± 90.0	93.1 ± 11.0*	9.9 ± 7.2*	2.3 ± 1.9*	230.9 ± 16.6*
RT-group	13	Pre	51.0 ± 14.9	193.6 ± 218.4	96.9 ± 13.7	9.7 ± 11.4	2.4 ± 3.0	229.9 ± 12.8
		Post	55.5 ± 16.1	143.8 ± 104.7	93.0 ± 8.3	8.0 ± 8.1	1.9 ± 2.2	228.8 ± 14.3
RTS-group	13	Pre	48.3 ± 16.7	217.2 ± 109.1	99.0 ± 18.1	16.0 ± 10.0	4.0 ± 2.7	242.2 ± 19.1
		Post	52.3 ± 19.6	157.9 ± 76.3*	93.2 ± 13.6*	11.7 ± 6.0*	2.7 ± 1.6*	233.1 ± 19.0*

Data are shown as mean + standard deviation, Pre = baseline data, Post = at the end of the 12 weeks intervention. Both groups with resistance training were summarized as a Training group.
RTS group:resistance training with soy protein supplementation, RT-group: resistance training only; HDL-C: high density lipoprotein cholesterol; HOMA: Homeostasis Model Assessment.
*$p < 0.05$ for intraindividual changes.

−28%, fructosamine: −2%; for all $p < 0.05$) and a significant increase in HDL cholesterol (+8%; $p < 0.05$) compared to the LE-G; participants of the RTS group who began the study with high triglyceride levels showed a significant decrease in post-invention triglyceride levels.

Pre- to post-intervention data regarding leptin and inflammatory markers are given in Table VII. Participants began the study with normal ranges for these measures in all groups, no significant changes in the parameters were found after 12 weeks in either the LE-G, RT or RTS group.

Discussion

Based on the hypothesis that both resistance training and post-exercise protein supplementation are responsible for an optimal adaptation in muscular and metabolic functions, the present study evaluated these two factors in a 12 week randomised controlled intervention study. An important finding of this study is that we were able to confirm the synergistic effect of resistance training and daily protein supplementation, given separately from conventional meals as a daily drink, on body composition and fat-free mass in middle aged men. Despite the lack of change in total body weight, resistance training in combination with protein supplementation led to significant increases in fat-free mass and significant decreases in fat mass and waist circumference. In contrast to the anthropometric data, there were comparable improvements in muscular strength and coordination after training, both with and without protein supplementation.

It can be speculated that changes in anabolic hormones may be responsible for increases in muscle mass as well as muscular strength [29–31]. However, the blood concentration of free testosterone as well as DHEA showed no intervention induced changes, neither in the RT, nor the RTS group. Therefore, it appears unlikely that training induced effects on these hormones are responsible for the documented improvements in body composition and muscular functions in the sample investigated. These results agree with the results of other studies which have reported no significant effects of physical training on sex hormones levels [29,32]. Nevertheless, it can be assumed that HGH rather than sex hormones may be the factor triggering the stimulation of muscle mass and muscular function. HGH activity is a regulatory factor of body composition and physical performance, particularly in aging subjects [29,33,34]. Human aging has been shown to result in a decline of HGH and the HGH/IGF-1 axis and with changes in body composition and muscular function [35,36]. Physical activity is an effective regulator of the HGH/IGF-1 axis, and physical fitness as well as regular strength training increases HGH production in the middle-aged and elderly [7,30,37,38].

The interactive effects of resistance training and protein supplementation on muscle mass and muscular function are less clear. As aging may be associated with reduced anabolic efficiency to a normal diet and less anabolic sensitivity to amino acids, there may be triggering mechanisms that counteract the anabolism of aging [29,30]. Recently published results show that soy interacts in the multimodal approach of training. First, amino acids of soy protein such as arginine and lysine may affect the somatotropic axis and promote HGH release and its anabolic action [39–42]. Second, soy proteins may improve the receptor mediated transport of insulin and leptin through the blood-brain barrier, e.g. by lowering plasma triglycerides [43,44], which leads to an increased activity of several hypothalamic proteins involved in the control of food intake and thermogenesis [45]. And third, soy isoflavones such as genistein may attenuate proinflammatory and catabolic pathways and cytokine expression in the human brain [46,47]. These cellular and molecular mechanisms may be central effectors for optimising peripheral muscular adaptation to resistance training in aging individuals, and finally, for the findings described with regards to body composition and muscular function illustrated in this study. In this study, the soy protein supplementation seemed to induce an increase in HGH in addition to the effect of the resistance training, as the increase in HGH was statistically significant only in the RTS-group. However, due to the lower HGH-level at baseline in the RTS-group the effect is difficult to estimate.

Table VII. Cytokines and inflammatory markers.

Group	*n*		Leptin (ng/ml)	IL-6 (pg/ml)	hs-CRP (mg/dl)	Fibrinogen (mg/dl)
Control group	9	Pre	17.7 ± 7.4	1.24 ± 0.31	0.18 ± 0.11	377.3 ± 60.0
		Post	18.9 ± 5.8	1.50 ± 0.86	0.24 ± 0.31	363.4 ± 42.1
Training group	26	Pre	17.7 ± 10.0	2.11 ± 1.94	0.15 ± 0.19	356.6 ± 60.7
		Post	16.8 ± 10.5	2.54 ± 2.38	0.14 ± 0.11	361.5 ± 57.5
RT -group	13	Pre	18.2 ± 10.7	1.48 ± 1.46	0.21 ± 0.26	341.3 ± 65.9
		Post	17.2 ± 11.3	1.71 ± 1.42	0.14 ± 0.10	351.7 ± 58.0
RTS-group	13	Pre	17.3 ± 9.7	2.73 ± 2.20	0.09 ± 0.07	371.8 ± 53.0
		Post	16.4 ± 10.2	3.37 ± 2.88	0.14 ± 0.11	371.4 ± 57.6

Data are shown as mean ± standard deviation, Pre = baseline data, Post = at the end of the 12 weeks intervention. Both groups with resistance training were summarized as a Training group.

RTS group:resistance training with soy protein supplementation, RT-group: resistance training only.

It is well documented that the soy–yoghurt–honey preparation used in this study augments weight loss without compromising muscle mass. We previously demonstrated an improvement of metabolic risk factors in postmenopausal women [19,48]. In this study, no effect on blood lipids or biomarkers of inflammation attributable to the supplementation was found. We speculate that the amount of soy protein consumed daily (27 g) was too low to induce these effects.

Although the intention of this study was to investigate changes in muscle mass and muscular function, it should be emphasised that resistance training combined with the intake of a protein-rich supplement improved the metabolic milieu of the participants of the RTS-group, particularly with regards to glycaemic control. All measures of glycaemic control were significantly improved after 12 weeks of intervention. As described before, subjects with less favourable metabolic biomarker levels show greater improvement in risk factor levels than subjects with clinically normal values at baseline. In addition, for both the RT-G and RTS-G it is important to note that supervised resistance training as applied in this study did not induce any adverse effects on serological markers of inflammation. In conclusion, it appears that resistance training in combination with protein supplementation is more effective in adaptation to muscle mass and muscle function than resistance training alone, and that soy protein supplementation supports anabolic and metabolic effects of resistance training in previously untrained middle aged males.

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Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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