Effects of Strength Training and Nutritional Counseling on Metabolic Health Indicators in Aging Women

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Catalogue Data

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Mots-clés: exercice physique, diète, personnes âgées, maladies cardiovasculaires, diabète

Abstract/Résumé

Purpose: Effects of strength training (ST) and nutritional counseling (NC) on metabolic health indicators were examined in 50 aging women. Methods: Subjects performed ST for 21 weeks. NC was given to obtain sufficient energy and protein intake, and recommended intake of fat and fiber. Results: NC increased intake of protein and polyunsaturated fat by 4.5% and 10.7% and decreased intake of saturated fat by 18.3%. Serum concentrations of total cholesterol (TC), LDL-cholesterol (LDL-C), total and HDL-cholesterol (HDL-C) ratio and triacylglycerols (TAG) decreased, and serum HDL-C increased in all subjects after ST. Respectively, systolic and diastolic blood pressure and serum insulin concentration decreased in all subjects. NC contributed to the decreases in levels of serum LDL-C after the first half of ST and serum TC and HDL-C ratio during both ST periods. Changes in serum TAG concentrations correlated positively with intake of carbohydrates, and negatively with monounsaturated fat in all subjects. Respectively, changes in serum TC levels were related

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to protein intake, and changes in serum HDL-C to intake of fat, and inversely to carbohydrate and protein in all subjects. Relationships between serum TC and HDL-C levels and protein intake were only observable in the ST+NC group. Conclusions: The long-term ST had favorable effects on serum lipids, lipoproteins, insulin concentration, and blood pressure. However, NC further contributed to positive changes in serum lipids and lipoproteins.

But: Analyser les effets de l’entraînement à la force (ST) et de conseils nutritionnels (NC) sur des indicateurs de la santé métabolique de 50 femmes vieillissantes. Méthodes: Les sujets s’entraînent à la force (ST) durant 21 semaines et reçoivent des conseils nutritionnels afin d’obtenir une bonne énergie par l’apport adéquat de protéines, de gras, et de fibres. Résultats: La consommation de protéines et de gras polyinsaturés augmente de 4,5% et de 10,7%, respectivement, tandis que la consommation de gras saturés diminue de 18,3%. Après la période d’entraînement à la force, on observe dans tout le groupe une diminution des concentrations sériques de cholestérol total (TC), de cholestérol LDL (LDL-C), du ratio de cholestérol total et de cholestérol HDL (HDL-C) et de triacylglycérols (TAG), et une augmentation du cholestérol HDL-C. On observe également chez tous les sujets une diminution des pressions systolique et diastolique et de la concentration sérique d’insuline. Les conseils nutritionnels ont contribué à la diminution des concentrations sériques de LDL-C durant la première moitié de ST et à la diminution du ratio de TC et de HDL-C durant les deux moitiés. Chez tous les sujets, les variations des concentrations sériques de TAG sont corréllées positivement avec l’apport de sucres et négativement avec l’apport de gras monoinsaturés. Chez tous les sujets, les variations des concentrations sériques de TC sont corréllées à l’apport de protéines; les variations des concentrations sériques de HDL-C sont corréllées positivement à l’apport de gras, mais négativement à l’apport de sucres et de protéines. On observe une relation entre les niveaux sériques de TC, de HDL-C et l’apport protéique que dans le groupe ST+NC. Conclusion: l’entraînement à la force sur une longue durée produit des effets bénéfiques sur les concentrations sériques de lipides, de lipoprotéines, d’insuline, et sur la pression sanguine. Les conseils nutritionnels contribuent à l’amélioration du profil lipidique.

Introduction

In industrial countries the mean age of the population is increasing. Old age is often associated with multiple diseases and pathological conditions, which increases the burden on public health services (Drewnowski and Evans, 2001). In the process of aging, both structural and functional changes take place in the body as a result of hormonal factors, decreased physical activity (especially in intensity), and diet. Consequently, both muscle mass and muscle strength decrease significantly especially after the 5th decade of life (Häkkinen et al., 2000; Morley, 1997).

Cardiovascular diseases (CVD) and type 2 diabetes (T2D) are among the leading diseases which cause mortality and a loss of functional capacity. Etiology and pathogenesis of these diseases have been implicated by genetic and environmental factors. Regular physical activity and healthy diet are among the most important lifestyle factors in the prevention and care of both CVD and T2D (Pollock et al., 2000; Tuomilehto et al., 2001).

Dietary intervention studies have demonstrated that especially improvements in the quality of fat (i.e., replacing saturated fat with unsaturated fat) can have a favorable effect on fat and glucose metabolism and reduce the risk for coronary
heart disease (CHD) and T2D. However, an increase in intake of fruits and vegetables, whole grains, and fish may also lower the risk for CHD and T2D (Hu and Willet, 2002; Hu et al., 2001). For example, a study with 162 healthy middle-aged men and women showed that nutritional counseling which focused on replacing saturated fat with unsaturated fat improved insulin sensitivity (8.8%) and decreased serum concentration of low-density lipoprotein cholesterol (−5.2%) during a 3-month period. However, such a beneficial effect of the fat quality on insulin sensitivity could not be observed in individuals with high fat intake (>37 E%), underlining the importance not only of the quality but also the quantity of total dietary fat (Vessby et al., 2001).

Both endurance training and strength training have been shown to promote positive effects on health related factors such as body composition, serum lipids, and glucose metabolism (Pollock et al., 2000). Neuromuscular adaptations during strength training have been examined extensively, but the effects of long-term resistance training and diet on metabolic health are less well documented. The main purpose of this study was to investigate the effects of strength training both with and without nutritional counseling on resting blood pressure, resting heart rate, fasting serum lipids and lipoproteins, fasting serum insulin, and fasting blood glucose in aging women. Our main hypothesis was that a combination of prudent diet and ST gives better results on metabolic health indicators than ST alone.

**Methods**

**DESIGN AND SUBJECTS**

Fifty women ages 49–72 years volunteered to participate in this study. They were randomly divided in two subgroups: (a) strength training (ST) and nutritional counseling (NC), and (b) ST only (Figure 1). The study lasted 23 weeks. The first 2-week period was a control period during which there was no ST. Thereafter, both groups began a supervised strength-training program for 21 weeks.

![Figure 1](image)

**Figure 1.** Experimental design. BC = body composition, S = strength, MHI = metabolic health indicators, DI = dietary intake, NC = nutritional counseling.
After receiving full information about the risks and discomforts of the study, the subjects gave their written informed consent to participate. The study was conducted according to the declaration of Helsinki and was approved by the Ethics Committee of the University of Jyväskylä, Finland. The subjects had to be free from hormonal or neuromuscular system disorders. No hormonal medications (except estrogen therapy) or beta-blocker medications were allowed. Also, physical activity contraindications (American College of Sports Medicine, 1995) and diseases (e.g., cancer, rheumatoid arthritis) that may affect nutritional state or basal metabolic rate served as exclusion criteria. About 60 women were called in for medical examination and 51 were chosen to participate in the study. Only one subject dropped out during the study period.

Almost all women were physically active and had participated in low-intensity and low-frequency recreational physical activities such as Nordic walking, swimming, or biking on a weekly basis, but none had been involved in systematic ST. There were no significant differences in physical characteristics between the experimental groups at baseline (Table 1).

MEDICATION

At baseline the number of subjects using medications in the ST+NC and ST groups were, respectively, 15 and 13 for hormone replacement therapy (HRT), 2 and 1 for cholesterol medication, 4 and 4 for blood pressure medication, and 3 and 8 for other purposes (pain, asthma, osteoporosis). Cholesterol-lowering margarine (i.e., containing plant sterols or stanols) were used by 6 subjects in the ST+NC group and 5 in the ST group at Week 0. Neither group had changes in the number of women using HRT. Medication usage remained the same in the ST+NC group during the study. In the ST group, however, by the end of the study 1 subject began cholesterol medication, 1 began blood pressure medication, and 3 began other medications. In the ST+NC group, 4 more subjects began using cholesterol-lowering margarine by the end of the study.

STRENGTH TRAINING PROGRAM

All women participated in the same supervised ST program for 21 weeks. A whole-body ST program concentrating mainly on the legs was undertaken twice a week. It consisted of 6 to 8 exercises per session of bilateral leg press, bilateral/unilateral knee extension, bilateral/unilateral knee flexion, standing calf machine, machine bench press and pec dec machine, lateral pulldown, elbow flexion and extension, abdominal crunch, trunk rotation and extension, and leg adduction and abduction exercises. All training sessions were supervised by trained professionals of the research team.

The training load was progressively increased throughout the experimental period and varied between 40 and 80% of maximum, while the number of reps per set decreased from 10–15 to 8–10 and finally 5–8. The ST program for the legs was a combination of heavy-resistance hypertrophic and explosive type of strength training. The leg exercises involved a typical heavy-resistance training protocol with a modest tempo and rest periods of 1–2 minutes between sets. About 20% of
the leg exercises were undertaken with light loads of 50% of maximum, performing the concentric part of the exercise as explosively as possible. The detailed strength training program has been described by Häkkinen et al. (2001). The subjects were asked to continue their normal recreational physical activities such as Nordic walking, cycling, or skiing 1 to 3 times a week during the ST program.

NUTRITION

The dietary intake of both experimental groups was registered in food diaries for 3 workdays and 1 weekend day at Weeks 0, 11, and 21. Food records were collected from the ST+NC group also at Week 2 after the first meeting with the nutritionist. A 4-day dietary diary is sufficiently long to yield valid data about energy and macronutrient intake at the group level, although systematic underreporting of at

### Table 1 Characteristics of the Two Experimental Groups (n = 25 + 25)

<table>
<thead>
<tr>
<th>Variable &amp; Group</th>
<th>Control Period (2 weeks)</th>
<th>Strength Training Period (21 weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Baseline</td>
<td>Adjusted mean change</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>ST+NC</td>
<td>58.8 ± 7.0</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>ST+NC</td>
<td>25.6 ± 3.4</td>
</tr>
<tr>
<td>Fat mass (%) (BIA)</td>
<td>ST</td>
<td>25.1 ± 3.1</td>
</tr>
<tr>
<td><strong>Leg circumference (cm)</strong></td>
<td>ST+NC</td>
<td>52.3 ± 4.6</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>ST</td>
<td>52.5 ± 3.5</td>
</tr>
<tr>
<td>1 Rep Max leg press (kg)</td>
<td>ST+NC</td>
<td>100 ± 23</td>
</tr>
<tr>
<td>ST</td>
<td>97 ± 19</td>
<td>101 ± 19</td>
</tr>
</tbody>
</table>

Note: ST = strength training, NC = nutritional counseling, BIA = bioimpedance (InBody 3.0, Biospace Co., Korea). a adjusted to baseline value, b group difference of the response.
least 20% is typical of this method (Buzzard, 1998). The subjects received verbal and written instructions to write down all food and drinks they consumed including portion sizes by household measures, the exact brand names, and the preparation technique. The food recordings were analyzed using the Nutrica® version 3.11 nutrient analysis software (Social Insurance Institution of Finland). If necessary, additional information was obtained from the food manufacturers’ network homepage or from the network database Fineli of the National Public Health Institute of Finland.

Nutritional counseling was given by an authorized nutritionist (Master of Health Science, Nutrition) at Week 0 and Week 11 (Figure 1). Both verbal and written instructions were given to the subjects individually so that they would obtain sufficient energy and protein intake as well as recommended levels of fat and fiber. Subjects were not instructed either to lose or gain weight. NC was based on dietary diaries and a personal interview. It was felt that sufficient dietary intake would be reached by recommendations of regular and balanced meals, i.e., breakfast, lunch, dinner, and 1 to 3 snacks. All meals would contain whole grain products, low-fat dairy or meat products, and vegetables or fruit. In addition, it was advised that at least 3 glasses of low-fat liquid dairy products (e.g., milk, sour milk, yogurt, or sour whole milk) be consumed daily to assure adequate calcium and vitamin D intake. In Finland milk and sour milk are enriched with vitamin D because of the prevalence of low vitamin D status (Lamberg-Allardt et al., 2001). With regard to the quality of fat, the subjects were asked to favor vegetable margarines and oils, to choose low-fat products, and to eat fish weekly.

In addition to verbal instructions, the subjects were given a Finnish Bread Association’s manual called “New Finnish Nutrition Guide” about healthy eating habits. This manual was based on the Finnish nutrition recommendations (Governmental Advisory Board on Nutrition, 1998). Subjects also received two memos to post on the refrigerator. The first memo gave recommendations on meal frequency, food choices, and meal composition. The second memo included a recommendation for daily portions of low-fat dairy and meat/fish products. A recommendation per portion should aim to guarantee about 1 gram of good quality protein per calculated body weight of body mass index 25 kg/m². The subjects were encouraged to follow these verbal and written instructions throughout the study period.

METABOLIC HEALTH INDICATORS

The metabolic health indicators used in the present study were lying resting blood pressure, lying resting heart rate, fasting serum lipids and lipoproteins, fasting serum insulin, and fasting blood glucose. These health indicators were measured during the control period and in the middle and end of the 21-week ST period (Figure 1). The day preceding the morning measurements was a day of rest from any strenuous physical activity and the subjects were instructed to get at least 8 hours sleep the previous night.

Blood and serum samples were taken after fasting in the morning, while the subjects lay supine after 15 minutes of rest. Blood pressure and heart rate (the lower value of the two measurements) were registered in the supine position after
15 minutes of rest. All blood samples were collected according to standardized laboratory practice. Serum samples were stored at –20 °C until analyzed. Blood glucose was recorded immediately by the quick-analyzer (B-Glucose photometer, Hemocue Ab Ängelholm, Sweden). Serum insulin concentrations were analyzed using radioimmunoassay kits from Pharmacia & Upjohn Diagnostics AB (Uppsala, Sweden). The sensitivity of the assay was below 2.5 mU/l, the intra-assay variation was 5.3%, and the interassay variation was 7.6%. Serum total cholesterol (TC), HDL-cholesterol (HDL-C), and triacylglycerols (TAG) were determined using the enzymatic assays (micro-flow spectrophotometer Shimadzu CL-720, Shimadzu Corp., Kyoto, Japan) and kits from Roche Diagnostics GmbH (Mannheim, Germany). LDL-cholesterol (LDL-C) concentration (mmol/L) was estimated using the Friedewald equation: LDL-C = TC – HDL-C – (TAG/2.2) (Friedewald et al., 1972).

BODY COMPOSITION AND MUSCLE STRENGTH

Body composition was assessed in the morning in a fasting state during the control period and in the middle and end of the 21-week ST period (Figure 1). Body mass index was calculated by dividing the subject’s weight (kg) by the square height (m²). Body weight was measured with a calibrated electrical scale (Model 708 [d = 0.1 kg], Seca, Germany), with the subjects in their underwear. Height was measured by an inelastic plastic tape measure with the subjects standing. Body fat % was recorded by the bioimpedance analyser (InBody 3.0, Biospace Co., Seoul, Korea) using the manufacturer’s built-in equation. Subjects were asked not to perform any stressful physical exercise, not to take a long hot sauna, but to drink normally the day preceding the measurements, and to void in the morning prior to the bioimpedance measurement.

Leg and waist circumferences were measured in the standing position using an inelastic plastic tape measure. The average of two measures was recorded. Leg circumference was identified as the middle of the line between the knee joint gap and the trocanter major. Waist circumference was identified as the middle of the line between the lowest rib and the iliac crest. Maximal leg extension strength was measured during the control period and in the middle and end of the 21-week ST period using the bilateral concentric 1-RM horizontal leg press (starting from a knee angle of 70° to full extension at 180°) using the modified David 210 device (Häkkinen et al., 2000).

STATISTICS

SPSS 9.0 for Windows was used for statistical analyses. Standard statistics were used for descriptives (means, SD, and SEM). Group differences were studied with covariance analyses using the baseline values as the covariate. If no group effects were found, the time effect was analyzed in the total group of subjects using multivariate analysis of variances (MANOVA) with repeated measures. If necessary, the data were transformed logarithmically before MANOVA to fulfill the criterion of normal distribution. The criterion of p < 0.05 was used for statistical significance.
After 21 weeks of strength training, the body mass index and % body fat decreased more in the ST group compared to the ST+NC group (Table 1). No group differences were observed in the changes of body circumference and gains in muscle strength after ST. In all subjects, strength training decreased waist circumference by \(-1.9 \pm 4.0\) cm \((p = 0.002)\) and increased leg circumference by \(3.4 \pm 3.1\) cm and maximal leg strength by \(27.1 \pm 8.1\) kg \((both \ p < 0.001)\).

There were differences in intakes of protein, saturated fatty acids (SAFA), and polyunsaturated fatty acids (PUFA) between the experimental groups when mean dietary intake was compared during the ST period (Table 2). The differences between groups were caused by the changes in the ST+NC group, while nutrient intake remained unchanged in the ST group. An increase of \(4.5\%\) in protein intake \((95\%\ CI: 1.1\% \ to \ 8.5\%)\) and of \(10.7\%\) in polyunsaturated fat \((5.4\% \ to \ 17.9\%)\), and
a decrease of 18.3% in saturated fat intake (24.6% to 11.9%) were recorded in the ST+NC group.

After the first half of the 21-week ST period, serum LDL-C concentration and the serum TC/HDL-C ratio were significantly lower in the ST+NC group than in the ST group (Figures 2 and 3). At the end of the study, the ratio of serum TC and HDL-C concentration still remained lower in the ST+NC group than in the ST group. There were no differences between groups in the changes of serum TC, HDL-C, and TAG concentrations during training (Figures 4, 5, and 6). In all subjects, serum TC levels decreased after the first half by $-0.7 \pm 0.6$ mmol/L ($p < 0.001$) but then increased during the second period of ST. At the end of the ST period, however, serum TC concentration was still slightly lower ($-0.1 \pm 0.4$ mmol/L, $p = 0.002$) than baseline values. Serum HDL-C levels decreased slightly ($-0.1 \pm 0.2$ mmol/L, $p = 0.003$) during the first part of the training period in all subjects, but rose ($0.3 \pm 0.2$ mmol/L, $p < 0.001$) to higher levels than at baseline in the second half of the training period. There were no changes in serum TAG concentrations after the first half of training, but after the second period of ST the concentrations decreased slightly ($-0.1 \pm 0.3$ mmol/L, $p = 0.015$) compared to baseline values in all subjects.

During the ST period the relative changes in serum TAG levels and carbohydrate (g/kg: $r = 0.309$, $p = 0.032$), as well as monounsaturated fat (MUFA) intake ($r = -0.294$, $p = 0.043$), correlated with each other in all subjects. The relative changes between serum TC concentrations and protein intake (E%: $r = -0.340$, $p =$

![Figure 2. Serum LDL-cholesterol concentration (mean ± SEM) in the experimental groups ($n = 25 + 25$) during the study period. ST = strength training, NC = nutritional counseling. *Group difference of the response, $p = 0.025$.](image-url)
**Figure 3.** Ratio of serum total and HDL cholesterol concentration (mean ± SEM) in the experimental groups \( (n = 25 + 25) \) during the study period. ST = strength training, NC = nutritional counseling. *Group difference of the response: *\( p = 0.002 \); #\( p = 0.031 \).

**Figure 4.** Serum total cholesterol concentration (mean ± SEM) in the experimental groups \( (n = 25 + 25) \) during the study period. ST = strength training, NC = nutritional counseling.
Figure 5. Serum HDL-cholesterol concentration (mean ± SEM) in the experimental groups (n = 25 + 25) during the study period. ST = strength training, NC = nutritional counseling.

Figure 6. Serum triacylglycerol concentration (mean ± SEM) in the experimental groups (n = 25 + 25) during the study period. ST = strength training, NC = nutritional counseling.
0.018; g/kg: \( r = -0.365, p = 0.011 \) were correlated in all subjects during the training period. Respectively, the serum HDL-C levels correlated with fat (E%: \( r = 0.289, p = 0.046; \) g/kg: \( r = 0.308, p = 0.033 \)), carbohydrate (E%: \( r = -0.315, p = 0.029 \)), and protein (E%: \( r = -0.323, p = 0.025 \)) intake in all subjects. The relationships between the changes in serum TC and protein intake (E%: \( r = -0.482, p = 0.017; \) g/kg: \( r = -0.563, p = 0.004 \)) as well as between serum HDL-C and protein intake (\( r = -0.512, p = 0.011 \)) were only observable in the ST+NC group. There were no statistically significant relationships between the changes of serum lipids and lipoproteins and dietary intake in the ST group.

After the first half of the training period, both resting systolic (SBP) and diastolic blood pressure (DBP) were lower in the ST group than in the ST+NC group (Table 3). At the end of the study, however, blood pressure was similarly decreased in both groups compared to baseline values. No group differences were recorded in resting heart rate (HR) during the ST period.

The relative changes in resting SBP and in the ratio of PUFA and SAFA (P/S-ratio) correlated (\( r = -0.414, p = 0.044 \)) with each other in the ST+NC group during the study period. In the ST group a significant relationship was observed between the changes of resting DBP and SAFA intake (E%: \( r = 0.439, p = 0.032 \)).

Fasting blood glucose and serum insulin concentrations did not differ between groups during the training. However, in all subjects at the end of the whole ST period, serum insulin concentration was lower than baseline values (\(-0.5 \pm 1.6 \text{ mU/L}, p = 0.014 \)). There were no systematic relationships between the changes in glucose and insulin levels and dietary intake during the ST period.

**Discussion**

The long-term strength training seemed to have favorable effects on serum levels of fasting lipids and lipoproteins and resting blood pressure in both groups. However, NC as constructed in the present study (twice, 11 weeks apart) further contributed significantly to the positive changes in serum lipids and lipoproteins during 21 weeks of strength training in these aging women. Favorable changes in serum lipids and lipoproteins as well as resting blood pressure were related to changes in the quality of dietary fat, suggesting that a diet with moderate amounts of mainly unsaturated fats can help prevent CVD and T2D.

To our knowledge there are no published studies about the effects of combined ST and NC in healthy, weight-stable aging persons. However, some studies have been published on the effects of combined ST and a weight loss diet (Demling and DeSanti, 2000; Kraemer et al., 1999). The strengths of the present study were its long supervised strength training period and repeated controls of neuromuscular fitness, dietary intake, and metabolic indicators. However, the results of the present study must be interpreted with care because the experimental design did not include a separate control group without ST. Yet it did include a control period during which no ST or NC were carried out. Nevertheless, we cannot exclude the possibility that the time effects were caused by something other than training alone. However, the unchanged dietary intake data in the ST group suggests that seasonal changes did not have an effect on our main results regarding the effects of NC.
Table 3  Metabolic Health Indicators During the 21-week ST Period in Both Groups (n = 25 + 25)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Control Period (2 wks)</th>
<th>Strength Training Period (21 weeks)</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control (M ± SD)</td>
<td>Middle Adjusted mean changea (95% CI)</td>
<td>p-valueb (95% CI)</td>
</tr>
<tr>
<td>Cardiovascular Indicators</td>
<td></td>
<td>Baseline (M ± SD)</td>
<td>p-value</td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>ST+NC</td>
<td>140 ± 17</td>
<td>3.0 (–1.1 to 7.2)</td>
<td>0.008</td>
</tr>
<tr>
<td>(mm Hg)</td>
<td>ST</td>
<td>137 ± 21</td>
<td>–5.0 (–9.1 to –0.9)</td>
<td></td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>ST+NC</td>
<td>83 ± 10</td>
<td>3.2 (0.5 to 5.9)</td>
<td>0.001</td>
</tr>
<tr>
<td>(mm Hg)</td>
<td>ST</td>
<td>81 ± 8</td>
<td>–3.4 (–6.2 to –0.7)</td>
<td></td>
</tr>
<tr>
<td>Heart rate (bts/min)</td>
<td>ST+NC</td>
<td>67 ± 8</td>
<td>–1.1 (–4.1 to 1.9)</td>
<td>0.538</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>66 ± 12</td>
<td>0.2 (–2.8 to 3.1)</td>
<td></td>
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<tr>
<td>Glucose Tolerance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood glucose (mmol/L)</td>
<td>ST+NC</td>
<td>4.9 ± 0.5</td>
<td>0.0 (–0.2 to 0.1)</td>
<td>0.876</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>4.7 ± 0.5</td>
<td>0.0 (–0.2 to 0.2)</td>
<td></td>
</tr>
<tr>
<td>Serum insulin (mU/L)</td>
<td>ST+NC</td>
<td>5.2 ± 3.1</td>
<td>–0.4 (–1.2 to 0.3)</td>
<td>0.758</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>5.3 ± 4.2</td>
<td>–0.3 (–1.0 to 0.5)</td>
<td></td>
</tr>
</tbody>
</table>

Note: ST = strength training, NC = nutritional counseling. a adjusted to baseline value, b group difference of the response.
The present increase in maximal strength of the leg extensors after the 21-week ST is similar to that reported earlier in aging women, ranging from 24 to 29% after prolonged ST (Häkkinen et al., 2000; 2001). The decrease in body mass index and % body fat in only the ST group during the ST period is in agreement with findings that resistance training for 12 weeks decreased fat mass by 1.3 to 1.8 kg in older persons (Campbell et al., 1994; 1995). The data indicates that the subjects in the ST group did not voluntarily increase their dietary intake enough to meet the increased demands of ST. Campbell et al. (1994) reported that regular ST can increase energy demands as much as 15% in older people. In the ST+NC group the average increase in energy intake during the ST period was twice as high as in the ST group, although the difference was not statistically significant. The data emphasize the importance of sufficient dietary intake to prevent unwanted weight loss during the training program.

The present positive effects of NC on serum lipids and lipoprotein levels are supported by the fact that the quality of ingested fat and fiber intake became consistent with the current Nordic recommendations, i.e., saturated fat about 10 E%, monounsaturated fat 10–15 E%, polyunsaturated fat 5–10 E%, and fiber ≥ 25 g per day (Nordic Council of Ministers, 1996) after NC. The decrease in total fat intake and especially the substitution of saturated fat with unsaturated fat has decreased TC and LDL-C (Hu and Willet, 2002; Perez-Jimenez et al., 2002). Also, an increase in dietary fiber (e.g., cereal, vegetables, fruit) intake could improve serum lipid levels (Fernandez, 2001). Because medication use did not change in the ST+NC group during the study, although the use of cholesterol lowering margarine became somewhat more common, it is reasonable to consider that most of the positive effect of NC was evoked by changes in dietary intake. Favorable effects of ST on serum lipids and lipoproteins are supported by data from Fahlman et al. (2002) and Behall et al. (2003).

The present relationship between serum TAG concentrations and carbohydrate intake is in line with a study of about 4,000 women 25–64 years of age (Yang et al., 2003). Diets high in monounsaturated fatty acids have been proven to lower plasma TAG concentrations compared with high carbohydrate diets (Ros, 2003), supporting the present inverse association between serum TAG levels and MUFA intake. A negative correlation between serum TC concentrations and protein intake support the data that replacement of carbohydrates by low-fat, high-protein foods can lower plasma levels of TC in healthy normolipidemic persons (Wolfe and Piche, 1999). The present NC evoked an increase in the proportion of protein in the diet concurrently with a decrease in SAFA and an increase in PUFA. The positive association between serum HDL-C and fat intake and the negative association with carbohydrate and protein intake is consistent with the literature confirming that a decrease in the proportion of fat in the diet lowers serum HDL-C concentration (Hu and Willet, 2002). The data indicates that a diet with a moderate amount of mainly unsaturated fats is advisable for healthy levels of serum lipids and lipoproteins.

With regard to the time profile, the present data showed that serum TC concentration decreased drastically during the first half of the 21-week ST period. This is well in line with other studies including periods of 11–12 weeks of ST (Behall et al., 2003; Fahlman et al., 2002). However, during the latter half of train-
ing, the serum TC level again increased. This observation is difficult to explain but it may be related to seasonal effect, e.g., summer holiday time (Yanovski et al., 2000). Interestingly, an increase in HDL-C did not become evident until the end of the 21-week ST period. Former studies (Banz et al., 2003; Behall et al., 2003) showing no influence of ST on HDL-C levels may have been too short to reveal this training adaptation. LDL-C concentration already decreased after the first half of the ST period, supporting the data from Fahlman et al. (2002) and Behall et al. (2003). The slight decrease observed in serum levels of TAG after the second half of the ST is consistent with some previous studies (Behall et al., 2003; Fahlman et al., 2002). It would be of clinical interest to also study serum lipid and lipoprotein adaptations to long-term ST in aging men and special groups such as type 2 diabetics and CVD patients.

In this study both resting SBP and DBP were higher in the ST+NC group than in the ST group after the first half of the 21-week ST period. At the end of the study, however, blood pressure was similar in both groups. The initial increase in blood pressure in the ST+NC group was unexpected because in a previous study a lifestyle modification including a diet (DASH diet) similar to that in the present study produced a more remarkable decrease in blood pressure than conventional nonmedical therapy (Appel et al., 2003). It is possible that factors other than diet and ST (e.g., psychological factors) could have affected blood pressure. Nevertheless, in the present study both SBP and DBP had decreased to the same extent in both groups after the 21-week ST period. The present observation, that the quality of fat was associated with blood pressure, is supported by a study with over 11,000 middle-aged subjects in which SAFA intake was positively related to blood pressure and P/S-ratio was inversely related to blood pressure (Stamler et al., 1996). This supports the concept that improvements in dietary intake can help prevent CVD and T2D.

The lowering effect of ST on blood pressure is supported by the meta-analyses of Kelley and Kelley (2000), who reported that SBP and DBP decreased by an average of $-3 \pm 3$ and $-3 \pm 2$ mm Hg during ST. The finding that resting heart rate did not change during the present prolonged ST is consistent with the findings of Haykowsky et al. (2000). The present results are of clinical value because even a modest decrease in blood pressure could reduce cardiovascular disease rates by 6–7%, stroke rates by 8–9%, and death rates by 5–6% (Stamler et al., 1996).

There were no differences in fasting blood glucose and fasting serum insulin concentrations between groups. In all subjects, fasting serum insulin levels decreased during the latter half of the 21-week ST period concurrently with the loss of body fat and reduction in waist circumference. Fat mass (especially truncal fat) appears to correlate negatively with insulin sensitivity, at least in persons with impaired glucose tolerance (Rosenfalck et al., 2002; Ross et al., 2002). The lack of effects of ST on fasting blood glucose in the present study may have been due to the fact that our subjects had apparently normal fasting glucose concentration. Further studies are needed to investigate the effects of combined ST and NC on glucose metabolism in aging men and type 2 diabetics.

The observation that NC did not further contribute to glucose metabolism may have been related in part to the experimental design, i.e., individual NC was given only twice during the whole study period. In some other studies counseling
has been much more drastic, involving several meetings at the beginning of the study and even monthly follow-up meetings thereafter (Knowler et al., 2002; Tuomilehto et al., 2001). Obviously, the effects of more frequent NC need to be examined during ST.

CONCLUSIONS

The present long-term strength training seems to have had favorable effects on serum levels of fasting lipids and lipoproteins and resting blood pressure in both experimental groups. However, nutritional counseling further contributed significantly to the positive changes in serum lipids and lipoproteins during 21 weeks of strength training in these aging women. Favorable changes in serum lipids and lipoproteins and in resting blood pressure were related to the changes in quality of dietary fat, suggesting that a diet with moderate amounts of mainly unsaturated fats yields good metabolic health indicators. The data indicates that strength training combined with a healthy diet might be suitable for helping to prevent cardiovascular disease and type 2 diabetes in aging women.

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