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Effects Of Combined Strength And Endurance Training On Physical Performance And Biomarkers Of Healthy Young Women

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Short title: Training affects positively physical performance and health

1 Abstract

2 Cardiovascular fitness has decreased and obesity has increased in youth-adults world-wide
3 during the last ten years. Therefore, there is an urgent need to find out optimal exercise
4 training programs for improving physical performance and health outcomes, especially, among
5 sedentary women. Subjects were 25-30-year-old females with very low physical activity, and 65
6 % of them were overweight (BMI >25). They performed endurance and strength training three
7 times a week for nine weeks. Independent strength training and instructed endurance training
8 by indoor cycling were prescribed. Measurements were performed before, in the middle and
9 after the training period. No nutritional guidelines were given to the subjects. The 9-week
10 training period led to 8.5 % increase in estimated maximal oxygen uptake. Maximal isometric
11 strength of the leg and arm extensors as well as trunk flexors and extensors increased by 28.9
12 %, 7.8 %, 27.2% and 16.1%, respectively. Total cholesterol values lowered by 7.6 %, and high
13 density lipoprotein increased by 8.8 %, while low density lipoprotein, haemoglobin, serum
14 glucose and triglyceride remained unchanged. Serum cortisol increased by 22.7 % but no
15 changes in plasma testosterone, estradiol or sex hormone binding globulin were observed. The
16 skeletal muscle mass increased by 0.8 % without other changes in body composition. Our
17 results indicated that only 27 combined endurance and strength training sessions in 9 weeks
18 improved maximal endurance and strength capacity as well as some health outcomes. Thus,
19 combined strength and endurance training itself can induce significant health benefits without
20 the necessity of changes in dietary habits.

21 Key words: Sedentary women, physical training, body composition, physical fitness, hormone,
22 blood lipids

23 INTRODUCTION

24 It is well established that incorporation of physical activity and exercise into persons' lifestyle
25 improves their health and quality of life (22). In particular, regular exercise routines are
26 advocated as a major element in body weight loss-management programs (21) as either a
27 primary or adjunctive therapy. This is a critical consideration for many persons in light of the
28 world-wide epidemic in obesity (23).

29 Recommendations by health agencies vary as to how much regular exercise and what type of
30 exercise are necessary for optimal health. For example, the World Health Organization,
31 Institute of Medicine, Center for Disease Control and Prevention are all strong proponents for
32 the need for regular exercise, but the individual guidelines they have issued are not in total
33 agreement. The variance in these guidelines has led to some confusion in the public as to what
34 and how much to do in conducting an exercise regimen (5). Thus it is important to know how to
35 develop training programs among people without preceding physical activity (especially
36 women), and how quickly we can observe physiological and physical changes.

37 Modern life presents many advantages in time saving, but many young adults have a sense that
38 their lives are extremely busy, too demanding, and full of stress. For example, a study
39 commissioned by the United Kingdom health nutrition retailer Holland & Barrett revealed 68%
40 of those questioned believe today's young adult generation are forced to endure more
41 hardships than the previous generation at a comparable age (n > 4000; 20). In Canada, a
42 national survey found that 90% of adult respondents felt high levels of daily "role overload,"
43 and that they were pushed daily to do too much and too many things at once (8). A survey by
44 the American Psychological Association found 35% of adults polled since 2007 reported feeling

45 more stress now compared to years earlier, and 53% said they received little or no support
46 from their health care providers in coping with that heightened stress (2). These findings were
47 especially applicable to young adults (2) and within that group more so young women,
48 particularly if they were mothers (3). Regular exercise is recognized as a non-pharmacological
49 means of dealing with the psychological and physiological consequence of life stress (7,12). Yet,
50 in a busy lifestyle it can be difficult for adults to find the time to meet the complete exercise
51 recommendations of health agencies.

52 In light of the above points and due to a lack of scientific studies of physical training of
53 sedentary individuals, it is clearly relevant to understand effects of training in sedentary young
54 adults, especially women, who seek to maintain or regain aspects of their overall health. The
55 ultimate aim of the present study was to examine the influence of an exercise training program
56 of combined strength and endurance exercise activities designed to be manageable to lifestyle
57 demands (3 days per week, 9 weeks) on selected parameters of physical health and well-being
58 in young adult women. This was chosen to do without nutritional guidance to our participants
59 so as to focus on the impact of exercise training alone. It was hypothesized that physical fitness
60 would improve and some health biomarkers would change positively while no changes were
61 expected in body composition (due to training volume exposure).

62

63

64 **METHODS**

65 *Experimental Approach to the Problem*

66 Among sedentary people, a beginning of training should be safe with low volume and intensity. In the
67 gym, a supervisor should also teach correct techniques for each movement. In this way, it is possible to
68 prevent injuries and/or troubles in the cardiorespiratory functions. However, there is a real lack of
69 studies among truly sedentary individuals, concerning how much training and with what kind of
70 progression is efficacious in improving physical fitness and body composition. These points were a key
71 motivation in pursuing this study, where the sedentary women trained using combined strength and
72 endurance training for 9 weeks without nutritional guidelines.

73

74 *Subjects*

75 Seventeen young women, without any training history, volunteered to participate in the present study.
76 The criteria for their acceptance were that they had to be sedentary, 25-30 years old and without any
77 hormonal contraceptive use. Their occupations involved them mainly working at offices. A final
78 selection of the subjects was done after screening their physical activity, health and use of medicines
79 according to a questionnaire they completed. All the subjects were informed of the benefits and risks of
80 the investigation prior to signing an institutionally approved informed consent document to participate
81 in the study. They also were given a permission to withdraw from the study at any point. The Ethical
82 Committee of the University of Jyväskylä gave an approval statement for the present study.

83 The initial mean (\pm SD) age of the subjects was 27 ± 2 years (range 25-30 years), body height 168.2 ± 5.3
84 cm (range 163.0-178.0 cm), body mass 72.3 ± 12.9 kg (range 54.9-100.0 kg), and body mass index (BMI)
85 25.7 ± 4.6 $\text{kg} \cdot \text{m}^{-2}$ (range 17.6 - 33.8 $\text{kg} \cdot \text{m}^{-2}$). A total of 65 % of the subjects were overweight or obese
86 (BMI > 25.0), while 29% were in their normal weight (BMI = 18.5-24.9 $\text{kg} \cdot \text{m}^{-2}$) and 6 % underweight
87 (BMI < 18.49). The mean body fat was 32.8 ± 8.6 % (range 17.4-45.7 %) at the beginning of the study.

88

89 *Procedures*

90 The subjects were initially tested twice, within an interval of one week, before the training intervention
91 (PRE1 and PRE2). Thus the subjects served as their own controls. They were asked to maintain their
92 physical activity and nutritional behaviour unchanged during the study period. After the two PRE
93 measurements, they started their training programme of combined endurance and strength exercises
94 for a 9-week period. All subjects were then tested after 4 (AFTER4) and 9 (AFTER9) weeks. All tests and
95 measurements were performed at the same time in the morning, and the subjects were guided to have
96 the same nutritional and hydrational status.

97 The participants trained 3 times a week during the 9 weeks. During the first 7 weeks, they performed
98 two strength and one endurance training sessions while during the two last weeks, they performed two
99 endurance and one strength training sessions. Because the aim of the present study was to focus only
100 on the effects of exercise, they did not receive any nutritional guidelines. However, the participants kept
101 food diaries during three days within each week including one weekend day. They were asked and
102 instructed to write down all food they ate as accurately as possible.

103

104 *Training*

105 Endurance training consisted of spinning intervals with BodyBike indoor cycles (BodyBike International;
106 Frederikshavn; Denmark). These researcher guided training sessions lasted from 30 min in the beginning
107 of the training period to 55 min by the end of it. Mean intensities of cycling varied from 85 to 91 % of an
108 individual maximal oxygen uptake. All training sessions were individually guided by monitoring heart
109 rate (Firstbeat Memory Belt and Monitor software, Firstbeat Technologies, Jyväskylä, Finland). The
110 participants also utilized a Fitness Trainer software (Firstbeat Technologies, Jyväskylä, Finland), where
111 each participant had her own profile, and they also saved all their training and activity levels there.

112 Furthermore, the subjects were asked to maintain their normal lifestyle and not allowed to start any
113 other new training programme or sport events.

114 Strength training was performed in a gym according to individual guidelines. The participants trained
115 individually, mainly with TechnoGym equipment (TechnoGym, the Wellness Company; Cambettola;
116 Italia) and free weights. At the beginning of each week, updated training programmes (movements,
117 repetitions and weights) were given to each participant. The main training exercises were leg press,
118 knee extension and flexion, toe rise, lateral pull down, bench press, biceps curl, triceps curl, back
119 extension and abdominal curl. During the training period, intensity of loading increased gradually, and
120 repetitions varied from 5 to 15 according to the load. During the first training week, for preventing
121 injuries and learning correct exercise techniques, the participants performed more repetitions with
122 lighter loads and a shorter recovery period as in the subsequent weeks (see table I).

123

124 *Measurements*

125 Maximal aerobic capacity ($VO_2\text{max}$) was indirectly determined using a graded cycle ergometer tests
126 (Ergoline 800S, Bitz, Germany). A progressive protocol was used with an initial power output of 75 W
127 and increased by 25 W every 2 min until exhaustion (i.e, until volitional fatigue or a decrease of
128 pedalling cadence under 60 rpm/min). Heart rate was continuously recorded and monitored during the
129 test using memory belts (Firstbeat Technologies; Jyväskylä; Finland). The heart rates were analysed with
130 Firstbeat Sports software (Firstbeat Technologies; Jyväskylä; Finland) for estimating $VO_2\text{max}$.

131 Bilateral maximal isometric leg extension and arm extension forces were measured using dynamometers
132 for leg press and bench press, respectively. Knee angle was set to 107° with a goniometer, and
133 participants hands were placed on handle grips for the leg extension test (23). During the maximal
134 bench press protocol, participants were in a supine position with their back flat on a bench and feet flat

135 on the floor, with elbows and shoulders positioned at angles of 90°. Warm-up included at least two
136 submaximal trials prior maximal trials. A total of three maximal trials were performed with 30 s recovery
137 between trials. The best performance was included for further analysis. The participants were instructed
138 on the testing protocol and correct technique for each test action prior to testing. They were also
139 instructed to produce maximal strength as fast as possible and to maintain it for three seconds.
140 Furthermore, they were encouraged by a research personnel during the maximal efforts.
141 In the maximal back and abdominal curls, the participants stood and they were tightly fixed with a belt
142 around their hip and torso. A strain gage transducer was placed at the level of their chest. Then
143 participants isometrically extended (back) or flexed (abdominal) their torso for 3 s. The best result from
144 3 trials was selected for further analysis.

145

146 *Blood samples*

147 Fasting (10-12 h) blood samples were drawn from the antecubital vein in the morning. Only water was
148 allowed to be consumed ad libitum before the samples were drawn. They were collected into two
149 vacuum tubes 5/2 ml K2E (B&D Vacutainer, Plymouth, UK), one 5/3 ml serum gel tube (B&D Vacutainer,
150 Plymouth, UK) and one 5/2 ml FX-tube (B&D Vacutainer, Plymouth, UK). Haematological analyses were
151 done immediately after blood draws with a Sysmex KX 21N-analyzer (Sysmex Co., Kobe, Japan). Serum
152 gel tubes and FX-tubes were centrifuged at 3500 rpm for 10 min. Thereafter, total cholesterol (CHOL),
153 high density lipoprotein (HDL) and triglycerides (TRIGLY) were analysed with Konelab 20 XTi-analyzer
154 (Thermo Fisher Scientific Oy, Vantaa, Finland). Serum low density lipoprotein (LDL) was calculated
155 according to the equation of Friedenwald et al. (10). The serum samples were stored in -80 °C until
156 hormone analyses. Plasma glucose was also analysed with a Konelab 20 XTi analyser (Thermo Fisher

157 Scientific Oy, Vantaa, Finland). Serum hormones (testosterone, cortisol, estradiol) and SHBG were
158 analysed with an Immulite 1000-analyzer (Siemens Healthcare Diagnostics LA, Ca, USA) (9).

159

160 *Body composition*

161 Body mass and composition were analysed with a bioelectrical impedance analysis (BIA) (Inbody 720,
162 Seoul, South Korea) after an overnight fast of 10-12 h, to determine fat mass (FM), body fat percentage
163 (BF%) and fat free mass (FFM). Body mass and height were measured to the closest 0.1 kg and 0.1 cm,
164 respectively on a commercial scale. Body mass index (BMI) was calculated and waist circumference (WC)
165 was measured at the level of iliac crest after exhaling by a standard anthropometric tape measure.

166

167 *Statistical analyses*

168 After verifying data normality and homogeneity of variances, standard statistical methods were used for
169 the calculation of means, standard deviations (SD), standard errors (SE), Paired-Samples T-tests and
170 Pearson bivariate correlation coefficients procedures. Paired-Samples T-test was used to compare PRE1
171 with PRE2 to verify stability on the measured variables before training and further PRE2 with AFTER4
172 and AFTER9 (also AFTER4 with AFTER9) to determine the effects of training program on measured
173 parameters. The level of significance was set at $p \leq 0.05$. Analyses were carried out using statistical
174 software PASW for Windows 18.0.1.

175

176 **RESULTS**

177 During the 9-week training period, $VO_2\max$ increased by 8.5% ($p < 0.001$) by the end of training, with the
178 largest development occurred during the first 4 first weeks by 6.9% ($p < 0.001$) (Figure 1). At the same

179 time, time to exhaustion was prolonged significantly from 10:35±2:19 min:s to 11:55±2:17 (after 4
180 weeks, $p<0.001$) and 12:39±2:33 min:s (at 9 weeks, $p<0.001$). Furthermore, maximal power output
181 during the VO_2max test increased from 183±25 W to 199±26 W and 206±33 W ($p<0.001$), respectively.
182 No changes between the PRE1 and PRE2 measurements were noticed for any of these outcomes.

183
184 Maximal isometric bilateral force of the leg extensor muscles increased by 28.9% from 1911±182 to
185 2464±240 N ($p<0.001$) by the end of the training period, and by 11.2% ($p=0.053$) at the first four weeks
186 (Figure 2 A). In dynamic leg extension, one repetition maximum (1 RM) increased from 97.6±5.7 to
187 129.4±6.1 kg ($p<0.001$) and 10 repetitions maximum from 77.1±4.5 to 113.1±5.4 kg ($p<0.001$) by the end
188 of training. During the 9-week training period, maximal isometric bench press force improved by 7.8%
189 from 325±24 N to 350±29 N ($p=0.025$) but was not affected by the first 4-week period (Figure 2 B). The
190 rate of force development was unchanged throughout the study period. Maximal abdominal curl force
191 increased by 25.0% ($p<0.001$) and 27.2% (377±52 vs. 505±38 N, $p=0.011$) during the first 4-week and
192 entire training periods, respectively. Maximal back curl force was also increased by 16.1% from 488±43
193 to 566±43 N after 4 weeks ($p=0.058$) but not further after 9 weeks. No changes between the PRE1 and
194 PRE2 measurements were found in any of the present physical tests measured except in maximal force
195 of the leg extensor muscles, which was 10.8 % higher in PRE2 than in PRE1 ($p=0.006$).

196
197 Serum triglyceride concentrations did not change throughout the study, but total cholesterol values
198 decreased. This reduction was already apparent during the first 4 weeks of training (Table 2) and
199 reached 7.6% at week 9 ($p=0.046$). HDL increased by 8.8% ($p=0.012$) at week 9, and its changes were
200 positively correlated with the changes in VO_2max (Figure 3) and the changes in skeletal muscle mass
201 ($r=0.46$, $p<0.05$). LDL did not change ($p>0.05$), and fasting blood glucose also remained unchanged as
202 well as all these parameters when comparing PRE1 and PRE2 measurements (Table 2).

203

204 Serum testosterone, estradiol, and SHBG did not change during the training period (Table 3). However,
205 cortisol concentration increased from PRE2 to the end of the training period (i.e. at week 9; $p=0.014$).
206 No differences were observed in testosterone-SHBG-ratio and testosterone-cortisol-ratio as well as
207 between PRE1 and PRE2 values for any of these hormonal measures.

208

209 Total energy intake did not change from PRE to the 4- or to the 9-week training period assessment
210 (2043 ± 629 vs. 2049 ± 595 vs. 1842 ± 568 kcal/day, $p=0.223$), respectively. Neither any change was found in
211 consumed macro-nutrients: as carbohydrate relative contribution varied from 42.6 ± 4.6 to $47.86.9\%$, fat
212 from 35.4 ± 4.4 to $38.5\pm3.9\%$, and proteins from 15.1 ± 3.6 to $17.8\pm4.8\%$, respectively.

213 In body composition, there was a slight and significant increase in skeletal muscle mass (26.4 ± 9.8 vs.
214 26.6 ± 3.4 kg, $p=0.008$) during the 9-week training period, while body fat percent decreased (32.8 ± 8.6 vs.
215 $32.0\pm8.5\%$, $p=0.03$) during the first 4-week of training but not after that. Total body mass did not change
216 throughout the entire training period (PRE = 72.3 ± 12.9 , 4-week = 72.3 ± 13.3 , 9-week = 72.0 ± 13.1 kg).

217

218 DISCUSSION

219 Public health researchers have made many recommendations as to how much exercise should be done;
220 but what is an exact optimal amount that can match the time constraints of modern people, and hence
221 is manageable, is an issue of much debate (5). This study attempted to provide some insight on this
222 issue as we examined the influence of an exercise training program of combined strength and
223 endurance exercise activities, designed to be manageable to life-style demands, on measures of physical
224 health and well-being in young adult sedentary women. Indeed, we showed that both cardiovascular

225 and muscular functions were improved as were blood lipid profiles, and small positive but significant
226 changes also in body composition were observed in response to the training.

227

228 Regardless of the health organization, all agree that improvement of cardiovascular function is a key
229 element to enhancement of the overall health and quality of life in an individual (4). Our training
230 program succeeded in improving cardiovascular function as we observed a considerable and significant
231 increase in relative VO_2 max. These changes seemed to be due to true systemic and cellular adaptations,
232 and not just the function of total weight (mass) loss as no changes occurred in the latter measure and
233 aerobic performance was enhanced (i.e., time to exhaustion and peak power output). The magnitude of
234 change detected agrees with previous findings using similar subject populations and elements of
235 combined training. For example, Ho et al. reported a 13.3% increase in VO_2 max while Blake et al. (2000)
236 found closer to 20% increases (15). However, the study of Ho et al. involved a 12-week training period
237 with 5 days per week training, while the study of Blake et al. used 14 weeks – 3 days per week regimes
238 (6,15). Hence, those studies had slightly greater training dosages compared to our program.

239 Nonetheless, our findings track well with the magnitude of change within those studies, but clearly
240 demonstrate that significant alterations can occur in less time and with few training sessions per week in
241 the exercise program.

242

243 Muscle function is another key element to improved overall health and quality of life in individuals (22).
244 We found substantial changes in several key muscular parameters; e.g. maximal isometric and dynamic
245 strength in the lower limbs, upper body as well as trunk extension and flexion. The muscle groups
246 displaying these changes and the magnitude of the change corresponds with previous work from our
247 research group (16,19), but these earlier works focused primarily on males. The current work in women
248 supports that the positive muscular benefits of combined training are applicable across the genders.

249 When endurance-cardiovascular and strength-resistance exercise training are used in combination there
250 is always the question of adaptive “interference”. That is, in the landmark study by Hickson, he
251 demonstrated that when combined endurance and strength training was conducted concurrently
252 maximal strength performance is compromised (14). The inference concept is an issue of much debate
253 right now in the exercise science research community facilitating a large number of current studies on
254 the topic. A series of such studies from our research group have shown that during more realistic
255 training programs (i.e. less intensive than that used by Hickson, (14)) for physically active but
256 systematically untrained populations, consisting of a much lower training frequency (i.e., 2-3 sessions
257 endurance and strength, respectively), adaptations in strength and power development as well as
258 muscle growth are not compromised (13,19). Furthermore, a most recent study from our group has
259 shown that the increases in endurance performance were larger in magnitude when strength and
260 endurance were performed on different days in comparison with that produced by same-session
261 training (9). This latter study has also shown that body fat mass decreased only following combined
262 strength and endurance training performed on the different days. Thus, “separating strength and
263 endurance training into more frequent sessions performed on the different days seems to be a valid
264 option for healthy adults who wish to simultaneously optimize body composition and improve physical
265 fitness” (9). This work by Eklund et al. is well in line with and support of the present findings (9).

266
267 Our prescribed exercise training program worked well in improvement in both cardiovascular and
268 muscular performance. The magnitude of improvements did tend to be larger in muscle performance
269 (~8 to 29% increases) than cardiovascular performances (~8.5 to 12.5%). Whether this is due to the
270 strength programme (Table 1) being more optimal in design for our subjects or perhaps their initial very
271 low level of muscular fitness (which would allow greater improvement) is unclear and cannot be verified
272 from our data (1). Nonetheless, we have no reason to suspect that other women with the characteristics

273 of our study population would not experience similar positive improvements in cardiovascular-muscular
274 functionality.

275

276 Assessment of blood parameter responses is a critical diagnostic means for healthcare providers to
277 quantify the medical implications of an exercise training program. To this end we found that total
278 cholesterol was significantly decreased and HDL-cholesterol was increased. These are two critical
279 parameters indicative of positive cardiovascular adaptation and these findings are in agreement with
280 numerous previous findings and are extremely positive health outcome (see review by Leon and
281 Sanchez, 17). There were no changes in LDL-cholesterol, triglycerides, or glucose. However, at the end of
282 the study (9 week) serum cortisol concentration was significantly elevated. We speculate that this
283 hormonal response was also a positive training adaptation reflecting in our participants becoming better
284 at lipid metabolism, a common training adaptation (1). We venture that this was mediated in part by the
285 higher cortisol observed evoking a greater level of fat oxidation as this hormone is a key lipolysis
286 regulator (11,12).

287

288 As mentioned, the body weight of our participants did not change over 9 weeks of training. This finding
289 was disappointing as body weight is usually a critical, and simple, indicator to sedentary individuals that
290 their training program is being effective (6). Nevertheless, there were significant changes within body
291 composition: a small increase in the muscle component (lean body mass) and decrease in the
292 percentage of body fat. Additional compositional changes (e.g., fat mass) and larger changes in muscle
293 with training programs of similar or slightly longer duration have been reported in earlier studies
294 (15,18,21). These latter studies have typically integrated a nutrition element to the program where
295 caloric energy and macro-nutrient intake have been modified. The combination of an exercise program
296 and nutritional modification are well established as efficacious means of substantially altering body

297 weight and composition (1). Our goal though was to focus only on the effect of an exercise training
298 program in our research subjects. The rationale for this approach was based upon the idea that inducing
299 too many changes in lifestyle and behaviour within the participants would be too demanding and likely
300 compromise compliance and completion of the training on their part.

301
302 As with any study there are limitations to our work. The addition of a control group would have
303 enhanced the interpretation of our findings. To counter this point we chose to have two pre-training
304 testing sessions to allow for a stable baseline assessment for the majority of our measurements. We feel
305 this allowed us to identify with a greater sensitivity the changes in our participants even without an
306 actual control group. Certainly the introduction of a nutrition intervention as a part of the study design
307 could have led to larger positive changes in many of our health biomarkers (e.g., blood lipids, body
308 composition). As noted earlier though, this was not a focus of our study and we tried to identify the
309 effects of exercise training alone.

310
311 In conclusion, the results of this study support the concept that women engaged in an exercise training
312 program of combined strength and endurance exercise activities designed to be manageable to lifestyle
313 demands can have positive health changes in a multiple of performance and health biomarkers. These
314 findings point to it being feasible that an efficacious exercise program can be conducted by individuals
315 living in a busy and demanding societal setting.

316

317 **PRACTICAL APPLICATIONS**

318 The present study has demonstrated that a limited exposure to combined strength and endurance
319 training can induce significant health benefits in sedentary women without the necessity of intervening
320 to change dietary habits. These benefits were achieved within the constraints of the busy life-style that

321 our subjects maintained. This is a critical finding as many people, especial women, find work-life time
322 limitation as a barrier to participation in a successful exercise program (6,22). Thus, for achieving good
323 health benefits, it can be recommended in sedentary women a combined strength and endurance
324 training three times a week with a high intensity (80-90% from the maximum) during the first 2-3
325 months of training.

ACCEPTED

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406 **FIGURE LEGENDS**

407

408 Figure 1. Mean (\pm SE) estimated maximal oxygen uptake (VO_{2max}) measured twice before (PRE1 and
409 PRE2) the training intervention, after 4 weeks, and after 9 weeks, i.e. at the end of the entire training
410 period. *** $p < 0.001$.

411

412 Figure 2. Mean (\pm SE) maximal force of the leg extensor muscles (A) and arm extensor muscles (B)
413 measured twice before (PRE1 and PRE2) the training intervention, after the training period of 4 and 9
414 weeks. *** $p < 0.001$; * $p < 0.05$.

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416 Figure 3. Relationship between changes in maximal oxygen uptake (VO_{2max}) and serum HDL
417 concentration during the 9-week training period.

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ACCEPTED

Table I. An individual example of the progressively increased strength training sessions. Recovery between the sets varied 45-60 s in the first week and 120-150 s in the last one.

	Weeks 1	Week 8
Leg press	3 x 15 x 80 kg	3 x 5-8 x 130 kg
Lateral pull down	1 x 15 x 15 kg	3 x 12 x 22.5 kg
Bench press	3 x 15 x 15 kg	3 x 5-8 x 30 kg
Biceps curl	1 x 15 x 5 kg	2 x 12 x 7 kg
Vertical rowing	1 x 15 x 4 kg	2 x 12 x 6 kg
Triceps curl	3 x 15 x 7.5 kg	3 x 5-8 x 20 kg
Back extension	1 x 15 x 20 kg	3 x 12 x 30 kg
Abdominal curl	1 x 15 x 20 kg	3 x 12 x 30 kg

Table 2. Mean (\pm SD) serum triglyceride, cholesterol; high-density lipoprotein (HDL), low-density lipoprotein (LDL) and glucose values in each measuring point after fasting. * $p < 0.05$; ** $p < 0.01$

	PRE1	PRE2	AFTER4	AFTER9
Triglyceride ($\text{mmol}\cdot\text{l}^{-1}$)	1.17 \pm 0.34	1.04 \pm 0.35	0.95 \pm 0.24	1.01 \pm 0.29
Cholesterol _{tot} ($\text{mmol}\cdot\text{l}^{-1}$)	5.0 \pm 0.5	4.8 \pm 0.3	4.6 \pm 0.3**	4.4 \pm 0.7*
HDL ($\text{mmol}\cdot\text{l}^{-1}$)	1.37 \pm 0.29	1.37 \pm 0.26	1.40 \pm 0.25	1.51 \pm 0.27*
LDL ($\text{mmol}\cdot\text{l}^{-1}$)	2.6 \pm 0.4	2.6 \pm 0.5	2.5 \pm 0.4	2.5 \pm 0.5
Glucose ($\text{mmol}\cdot\text{l}^{-1}$)	5.3 \pm 0.4	5.1 \pm 0.3	-	5.3 \pm 0.4

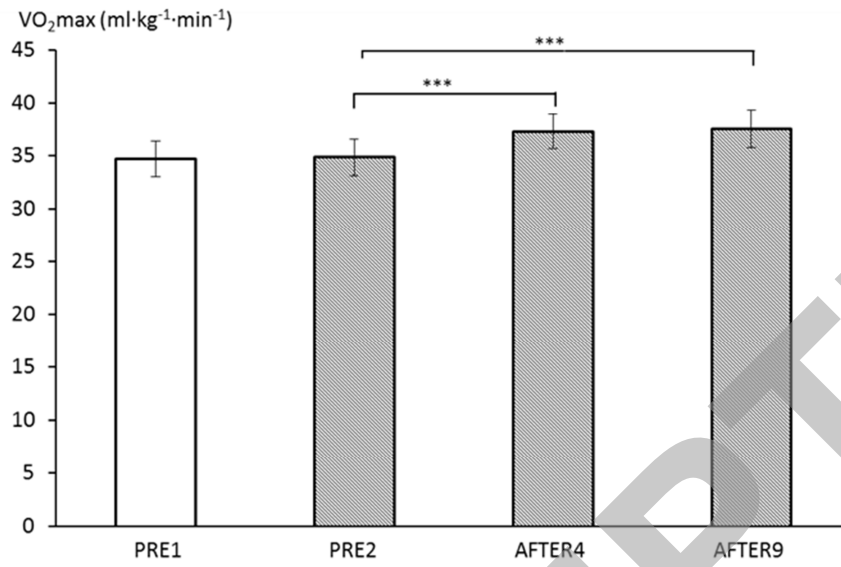
ACCEPTED

Table 3. Mean (\pm SD) serum testosterone, cortisol, estradiol, and SHBG values in each measuring point after fasting. **p=0.014

	PRE1	PRE2	AFTER4	AFTER9
Testosterone (nmol·l ⁻¹)	2.25 \pm 1.06	2.25 \pm 1.06	2.27 \pm 1.11	2.57 \pm 1.87
Cortisol (nmol·l ⁻¹)	524 \pm 129	439 \pm 86	439 \pm 96	563 \pm 134**
Estradiol (pmol·l ⁻¹)	453 \pm 371	461 \pm 455	461 \pm 271	505 \pm 355
SHBG (nmol·l ⁻¹)	56.2 \pm 16.4	58.2 \pm 14.6	58.2 \pm 15.3	55.6 \pm 22.5

ACCEPTED

FIGURE 1.



ACCEPTED

Figure 2.

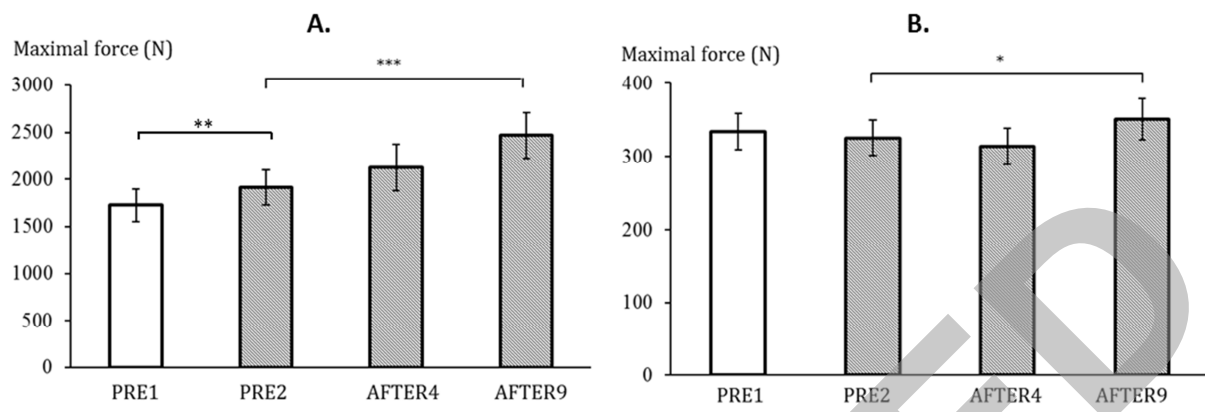
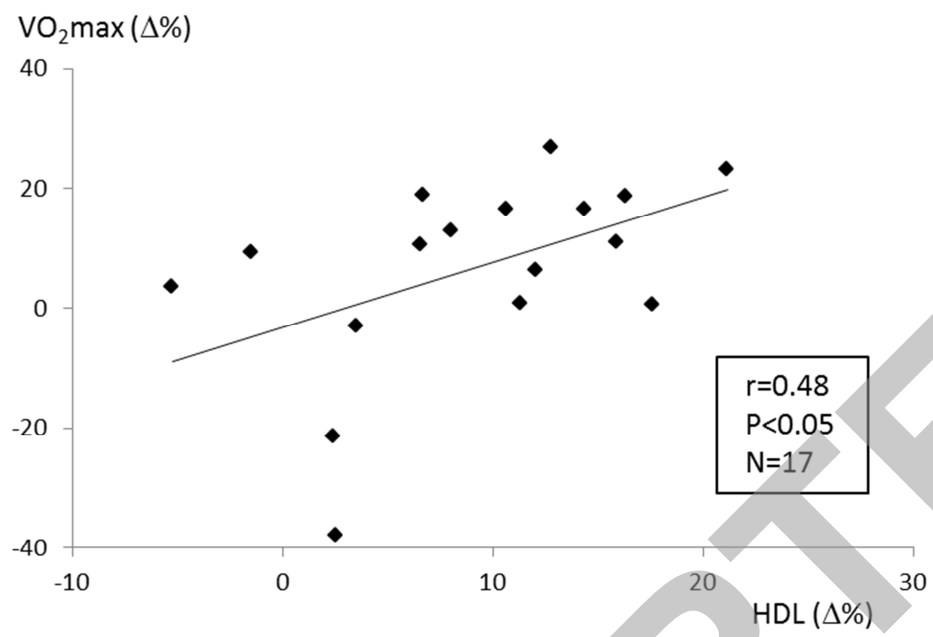


Figure 3.



ACCEPTED