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1 Maximum dynamic lower-limb strength was maintained during 24 weeks reduced training
2 frequency in previously sedentary older women

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5

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11

12 Running head: Reduced training frequency maintains strength up to 24 weeks

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26 ABSTRACT

27 There is little study into the effects of reducing strength-training below the recommended twice-
28 weekly frequency, particularly in older women, despite the possibility that individuals will encounter
29 periods of reduced training frequency. The purpose of the present study was to determine the
30 effects of a period of reduced training frequency on maximum strength and muscle mass of the
31 lower limbs in comparison with the recommended training frequency of twice-per-week. After an
32 initial 12-week period where all subjects trained twice-per-week, a reduced strength training group
33 (RST) trained once-per-week while another strength training group (ST) continued to train twice-per-
34 week for 24 weeks. A non-training age-matched control group (CON) was used for comparison. All
35 subjects were tested for leg press one-repetition maximum (1-RM), electromyogram (EMG)
36 amplitude of vastus lateralis and medialis and quadriceps cross-sectional area (CSA) measured by
37 panoramic ultrasound at week 0, 12 and 36. Both ST and RST continued to increase 1-RM during the
38 reduced training frequency period compared to control (~8% and ~5% vs. ~-3%, respectively,
39 $P < 0.05$). Accompanying these changes were significant increases in EMG amplitude in both ST and
40 RST ($P < 0.05$). However, the initial gains in quadriceps CSA made from week 0 to 12 in RST were lost
41 when training once-per-week (RST ~-5%). Therefore, reduced training frequency in this population
42 does not adversely affect maximum strength or muscle activity but can negatively affect muscle
43 mass, even reversing training-induced gains. Older individuals not training at least twice-per-week
44 may compromise potential increases in muscle mass; important in counteracting effects of aging.

45

46 KEYWORDS: Cross-sectional area, Quadriceps, Aging, 1-RM, EMG, Maximum force

47

48

49

50 INTRODUCTION

51 It is well accepted that strength training is a successful method to slow and in part reverse the age-
52 associated loss of strength and muscle mass. While clear guidelines on the type and duration of
53 physical activity has been published (31) and internationally recognized (i.e. 150 min of moderate
54 intensity or 75 min of vigorous aerobic activity per week for a minimum of 10 min per bout, strength
55 training twice-per-week and balance-enhancing exercise), data suggest that only 5–10% of adults
56 meet these recommendations (11, 30). Furthermore, typical adherence rates to strength training
57 programs have been reported to dramatically reduce after 3–6 months of initiating strength training
58 (30) and less than 1 in 5 has been shown to continue to train following a supervised strength training
59 intervention (27).

60

61 A significant lowering of training frequency or a complete cessation of strength training, otherwise
62 known as detraining, clearly shows reductions in strength and muscle mass (4, 6, 9, 10, 13, 14).
63 While complete cessation is the least desirable situation, less is known regarding periods of
64 continued strength training at a reduced training frequency. For example, even in those individuals
65 with high strength training frequency, periodical preference for aerobic or balance/motor skill
66 exercise over strength development may influence strength training frequency. Therefore, it is
67 possible that individuals will not maintain a strength training frequency of at least twice-per-week
68 throughout the year. Hence, it is pertinent to identify what frequency of strength training is
69 necessary to maintain previously achieved gains in strength and muscle mass.

70

71 Despite this potentially important information, few studies have investigated the effect of reduced
72 frequency strength training on strength and muscle mass. Tapering in athletes is an accepted form of
73 competition preparation and at least short-term (i.e. 1–4 weeks) reduced training volume appears

74 not to adversely affect performance (9, 16). Nevertheless, reduced training frequency in
75 recreationally active populations can last several weeks/months. The few studies that have
76 investigated reduced training frequency demonstrate that strength (10, 25) and muscle mass (2, 23)
77 can be maintained over relatively long periods with as little as one training session per week.

78

79 In the context of older individuals, Trappe et al. (23) showed that reduced training frequency of
80 once-per-week was superior to complete training cessation in maintaining strength and muscle mass
81 of the knee extensors. However, Bickel et al. (2) demonstrated that strength but not muscle mass
82 was maintained during reduced training frequency in older individuals whereas both strength and
83 muscle mass were maintained in the young subjects. These findings highlight a possibility that
84 muscle mass is not readily maintained in older subjects following reduced training frequency.
85 Furthermore, a well-controlled "unloading" study by Deschenes and colleagues (5) showed that
86 women suffered greater strength losses than men. Therefore, it is imperative to investigate the
87 potential implications of reduced strength training frequency in older women. Hence, the present
88 study reduced training frequency to a level below the recommended physical activity guidelines (i.e.
89 from twice- to once-per-week) after a period of twice-per-week strength training in a group of
90 healthy older women. The purpose was to determine the effects of this reduced training frequency
91 on strength and muscle mass of the lower limbs in comparison with the recommended training
92 frequency of twice-per-week.

93

94 METHODS

95 Experimental approach to the problem

96 Two groups of older women performed whole-body strength training twice-per-week for 12 weeks.
97 Thereafter, one group continued training twice-per-week (ST) while the other group reduced their

98 strength training frequency to once-per-week (RST) for a further 24 weeks. A third group maintained
99 their normal physical activity habits over the total 36-week period and acted as a non-training
100 control group. Measures of maximum dynamic strength with accompanying surface
101 electromyography (EMG), muscle mass and basal hormone concentrations were performed before
102 training (week 0), after the initial strength training period (week 12) and after the divergent
103 frequency strength training period (week 36). Also, maximum dynamic strength was assessed in the
104 two intervention groups after 24 weeks of training (i.e. in the middle of the divergent frequency
105 training period).

106

107 Subjects

108 Subjects were recruited by letters sent to a random sample of individuals living within the local area
109 (information obtained by the Population Register Center). After screening for suitability (21
110 registered subjects were removed at this stage), thirty-eight healthy older women (aged 64-75
111 years) volunteered to take part in the study. Inclusion criteria were; self-reported lower physical
112 activity level than the recommended guidelines, no strength training experience, BMI<37, free from
113 lower-body injuries, not taking medication that may influence the neuromuscular or endocrine
114 systems, and were non-smoking. All subjects were provided written and verbal details of the study
115 including possible harms and discomfort. Thereafter, the volunteers signed informed consent. The
116 study was cleared by the local ethics committee and performed according to the Declaration of
117 Helsinki. A physician examined all volunteers for medical history, existing conditions that may
118 preclude them for intense exercise and performed an echocardiogram prior to study
119 commencement. The volunteers were randomized into one of three groups – ST, RST and CON. Two
120 women from the control group dropped out of the study due to group assignment, resulting in a
121 final sample size of 36. Subjects' height was measured using a wall-mounted tape measure and
122 weight by commercial scales (Seca 708, Seca, Espoo, Finland).

123 Maximum dynamic strength

124 Following a familiarization session where the leg press device (David 210, David Sports Ltd, Helsinki,
125 Finland) was adjusted to each individual's limb length and practice trials were performed, the
126 subjects performed a concentric one-repetition maximum (1-RM) test. The starting knee angle was
127 $70 \pm 2^\circ$ of extension (straight leg = 180°). A warm-up was performed consisting of submaximal load
128 repetitions (8 at estimated 50% of maximum, 5 at estimated 60% of maximum, 3 at estimated 75%
129 of maximum, 2 at estimated 85% of maximum, 1 at estimated 90% of maximum). Thereafter, single
130 repetitions were performed with increments of 2.5-5 kg until the subjects could no longer voluntarily
131 extend their legs fully. This typically occurred within 3-5 trials with 1.5 min inter-trial rest given. Test-
132 retest reliability for bilateral leg press 1-RM was excellent, with an Intra-class Correlation Co-efficient
133 (ICC) of 0.935 and a Co-efficient of Variation percentage (CV%) of 3.9%.

134

135 Surface electromyography

136 Bipolar Ag/AgCl electrodes (5mm diameter, 20mm inter-electrode distance, common mode rejection
137 ratio $>100\text{dB}$, input impedance $> 100\text{M}\Omega$, baseline noise $<1\mu\text{V rms}$) were positioned following
138 shaving and skin abrasion on the vastus lateralis (VL) and medialis (VM) of the right leg according to
139 SENIAM guidelines. Raw EMG signals were sampled at 2000Hz and amplified at a gain of 500
140 (sampling bandwidth 10-500Hz). Raw signals were sent from a hip-mounted pack to a receiving box
141 (Telemetry 2400R, Noraxon, Scottsdale, USA), then were relayed to an AD converter (Micro1401,
142 Cambridge Electronic Design, UK) and recorded by Signal 4.04 software (Cambridge Electronic
143 Design, UK). Offline, EMG signals were band-pass filtered at 20-350Hz and root mean square was
144 obtained from approx. 70° of knee extension to full leg extension (i.e. 180°) during dynamic leg press
145 trials. Values for each muscle were taken from the best 1-RM trial and then averaged $(\text{VL}+\text{VM}/2)$.
146 Test-retest reliability was $\text{ICC}=0.871$, $\text{CV}\%=7.2$.

147

148 Quadriceps cross-sectional area

149 Cross-sectional area (CSA) measurements of VL and vastus intermedius (VI) of the right leg were
150 taken 1-2 days prior to dynamic leg press performance tests and 6-7 days after the final training
151 session to account for any exercise-induced swelling. CSA was assessed by B-mode ultrasound
152 (model SSD- α 10, Aloka Co Ltd, Tokyo, Japan) using a 10 MHz linear-array probe (60 mm width)
153 coated with water-soluble transmission gel with the extended-field-of-view mode (23 Hz sampling
154 frequency). This method has been used during several training studies (28, 29). Indelible ink tattoos
155 on the medial and lateral sides of the target muscles ensures accurate replacement of scanning
156 track. Oriented in the axial-plane, the probe was moved manually with a slow and continuous
157 movement from medial to lateral along a marked line on the skin. Great care was taken to diminish
158 compression of the muscle tissue. Images were obtained throughout the movement. As the
159 orientation of each image relative to adjacent images is known, the software builds a composite
160 image. Four panoramic CSA images were taken at 50% femur length from the lateral aspect of the
161 distal diaphysis to the greater trochanter. Upon visual inspection of the composite images three
162 were selected to undergo further analysis. CSA was determined by manually tracing along the border
163 of each muscle using Image-J software (version 1.37, National Institute of Health, USA). The mean of
164 the two closest values for each muscle were taken as the CSA result and then the sum of the two
165 muscles (VL+VI) was taken as the final value. Combined VL+VI test-retest reliability was ICC $r=0.926$,
166 CV%=4.0%. The same researcher performed the data acquisition and analyses.

167

168 Serum hormone concentrations

169 Basal blood samples (5 ml whole blood into Venosafe serum-separator tubes: Terumo Medical Co,
170 Leuven, Belgium) were obtained from an antecubital vein following an overnight fast (12 h) between

171 the hours of 7-9am. Samples stood at room temperature for 15 min and then were centrifuged for
172 10 min (3500 rpm at 4°C, Megafuge 1.0R, Heraeus, Germany). Serum samples were stored at -80°C
173 until the completion of the study and then analyzed for total testosterone (TT), sex-hormone binding
174 globulin (SHBG), cortisol (C), dehydroepiandrosterone sulfate (DHEA-S) and insulin using
175 immunometric chemiluminescence techniques (Immulite 2000, Siemens, Illinois, USA) with
176 hormone-specific immunoassays. In all cases, a pre-standard is analyzed to ensure that kits are
177 detecting within the required range, then single samples are run, any potential erroneous values are
178 checked and if necessary run in duplicate (and possibly also triplicate). Analytical sensitivity (nmol·L⁻¹)
179 and reliability (CV%) were 0.5 and 13%, 0.02 and 5.2%, 5.5 and 7.3% for TT, SHBG and C,
180 respectively.

181

182 Strength training program

183 The training groups performed whole-body strength training twice-per-week for 12 weeks with at
184 least 48 hours between sessions and each session was supervised by experienced gym instructors.
185 All exercises were performed on commercially available strength machines (Precor Vitality Series™,
186 Precor Inc, UK). Exercises included leg press, knee extension, knee flexion, chest press, lat pulldown,
187 shoulder press, seated row, bicep curl, triceps pushdown, ab curl and back extension. The 12-week
188 program was divided into a 4-week initiation phase (1min inter-set rest) and an 8-week super-set
189 training phase. Super-sets were: 1) Leg press+chest press, 2) knee extension+lat pulldown, 3) knee
190 flexion+triceps pushdown, 4) ab curl+back extension in session 1 and 1) Leg press+seated row, 2)
191 knee extension+shoulder press, 3) knee flexion+biceps curl, and 4) ab curl+back extension in session
192 2, with 1min rest between sets. The primary goal of this initial training period was to teach the
193 subjects correct technique for all exercises and to progressively increase the loads and reduce the
194 rest periods so that local muscular endurance was improved. Intensity for all upper and lower limb
195 exercises was approximately 50–60% of estimated 1-RM. All subjects were required to perform all

196 repetitions using a tempo of 2s concentric and 2s eccentric phase and at least 1 set should be
197 performed to concentric failure before completing the maximum number of allocated repetitions.
198 Repetition ranges used during the initiation phase was 16-20 and 14-16 during the super-set phase.
199 Whenever the subjects could perform the maximum number of allocated repetitions during all sets
200 without concentric failure the load was increased during the next session. The training groups then
201 continued to perform whole-body strength training at a frequency of either once- (RST) or twice-
202 (ST) per-week for 24 weeks (weeks 13–36) on non-consecutive days. This 24-week period was
203 divided into two 12-week mesocycles. The primary goal of mesocycle 1 was to increase maximum
204 strength and muscle mass. The primary goal of mesocycle 2 was to increase maximum strength and
205 power. Intensity for all upper and lower limb exercises was approximately 70–90% 1-RM with power
206 training performed using 30-80% 1-RM loads but maximum concentric velocity. Multiple sets (2-5)
207 were performed with repetition ranges of 4-12 and inter-set rest of 1-3min depending on the
208 training goal. All subjects were required to perform at least 1 set to concentric failure with the
209 exception of power training. All subjects were required to complete at least 90% of all allocated
210 training sessions prior to testing. The non-training control group was instructed to maintain their
211 normal physical activity throughout the study period.

212

213 Statistical analyses

214 All data were presented as means and standard deviations (\pm SD). All statistical methods were
215 performed using IBM SPSS statistics 24 software. The Shapiro-Wilk test was used to test normality
216 and Levene's test was used to analyze homogeneity of variance. Baseline differences for all
217 parameters were tested by means of one-way analysis of variance. Difference testing was performed
218 using repeated measures analysis of variance (ANOVA: 3 group \times 3 time) and Bonferroni post hoc
219 tests were performed whenever a significant group \times time interaction was observed. EMG data was
220 assessed by within-group repeated measures ANOVA with Bonferroni post hoc tests between time

221 points since the amplitude of the EMG signal cannot be compared between subjects. Effect sizes
222 (Hedges' g) were calculated for the differences in relative change (from week 13 to 36; i.e. before
223 and after the divergent frequency training period) between the intervention and control groups,
224 where small (<0.3), medium ($0.3-0.8$), and large (>0.8) effect sizes were identified. Statistical
225 significance was accepted when $P<0.05$.

226

227 RESULTS

228 Baseline characteristics for the groups are presented in table 1. There were no statistical differences
229 between groups.

230

231 A statistically significant group \times time interaction was observed in leg press 1-RM ($F=13.5$, $P<0.001$).
232 The intervention groups increased the load lifted during the initial 12-week period (RST: $P<0.001$,
233 95% confidence intervals (95%CI)= $7.1-17.1$ kg, ST: $P<0.001$, 95%CI= $6.9-16.8$ kg, Figure 1A) and then
234 both continued to increase the load lifted during the divergent frequency period (RST: $P=0.024$,
235 95%CI= $0.5-7.2$ kg, ST: $P=0.003$, 95%CI= $2.7-12.7$ kg, Figure 1A), whereas the control group did not.
236 Additionally, the relative changes in leg press 1-RM during the divergent frequency period showed
237 that the improvement in both intervention groups were greater than control (RST: $P=0.027$,
238 95%CI= $0.68-14.2\%$, $g=1.3$, ST: $P=0.001$, 95%CI= $3.9-17.0\%$, $g=1.6$, Figure 1B).

239

240 A significant main effect for time was observed in EMG amplitude recorded during the 1-RM
241 performance ($F=19.4$, $P<0.001$). EMG amplitude increased in the intervention groups in the
242 divergent frequency period (RST: $P=0.016$, 95%CI= $4.9-41.3\mu V$, ST: $P=0.01$, 95%CI= $5.3-48.6\mu V$, Figure
243 2). No changes occurred in the control group.

244

245 A statistically significant group×time interaction was observed in summed CSA (VL+VI) (F=3.7,
246 P=0.019). CSA increased in both intervention groups during the initial strength training period (RST:
247 P=0.072, 95%CI=-0.3–5.2cm², ST: P=0.031, 95%CI=0.9–2.3cm², Figure 3). Thereafter, no changes
248 occurred in the group training twice-per-week, but a trend of decreased CSA was observed in the
249 group training once-per-week (P=0.065, 95%CI=-2.9–0.8cm²) without between-group differences. No
250 changes occurred in the control group.

251

252 Significant main effects for time were observed in TT (F=15.1, P<0.001), TT:C ratio (F=5.6, P=0.007),
253 TT:SHBG ratio (F=11.8, P<0.001) and TT:DHEA-S ratio (F=8.8, P=0.001). Within-group comparisons
254 showed that TT increased throughout the study with a trended increase when training was
255 performed once-per-week (weeks 0-36: P=0.004, 95%CI=0.14–0.60nmol/L, weeks 13-36: P=0.061,
256 95%CI=-0.02–0.68nmol/L, Table 2). In the group that trained twice-per-week, an increase was
257 observed during the divergent training period (weeks 13-36: P=0.004, 95%CI=0.12–0.59nmol/L). Due
258 to the increase in basal TT but similar concentrations in other hormones, the ratios (TT:C, TT:SHBG,
259 TT:DHEA-S, Table 2) were also increased during the study. No changes occurred in the control group.

260

261 DISCUSSION

262 The present study showed that reduction of training volume to once-per-week did not adversely
263 influence improvements in leg press 1-RM in previously untrained older women undergoing
264 supervised training. It should be noted that although the divergent frequency training period
265 followed an initial 12-week training period, the potential for 1-RM improvement in this group of
266 subjects was still large in this group of previously untrained individuals. In addition, potentially
267 positive alterations in serum hormone profile were observed, and these alterations were

268 independent of training frequency. Otherwise, it appears that the initial increases in muscle mass
269 could not be maintained during a prolonged period of training once-per-week. This is a major finding
270 of this study since combating age-related loss in muscle mass is a primary goal of strength training in
271 this age group.

272

273 Naturally, large improvements occur at the beginning of a new exercise regime and the rate of
274 improvement reduces over time (12). Furthermore, it appears that training volume/frequency plays
275 a minor role in the immediate adaptations from an unfamiliar training stimulus (21). Consequently, it
276 was important to perform an initial period of strength training before the divergent frequency
277 training period. Following guidelines for initiating strength training in older individuals, the present
278 study's initial 12-week training period focused on using moderate loads (i.e. 40–60% 1-RM) and
279 higher repetition sets (14–20 reps). This practice may not be optimal to improve maximum strength
280 and muscle mass (3) and might be reflected in the magnitude of improvement in the intervention
281 groups. Whereas previous studies have shown increases in 1-RM of approximately 29–107% in older
282 individuals training over 12–24 weeks (8, 15, 21, 26), the intervention groups of the present study
283 improved by a mean of 17% and 14% (once-per-week and twice-per-week, respectively) over the
284 initial 12-week period. Nevertheless, both intervention groups improved at a statistically significant
285 level and differed from control. Additionally, muscle hypertrophy was observed by the initial
286 increases in VL+VI CSA (4.6% and 5.1%). Therefore, although the training program may not have
287 been optimal to increase strength and muscle mass, the subjects did demonstrate improvements in
288 both of these outcome measures and so the impact of reduced training frequency could be
289 evaluated.

290

291 During the divergent frequency period both intervention groups continued to improve 1-RM
292 performance. This matches the findings of Taaffe et al. (21) that observed similar increases in 1-RM
293 when older individuals trained once-, twice-, or three-times-per-week. Also, reducing training
294 frequency to below the current recommendations of twice-per-week did not disadvantage the older
295 women of the present study. Our findings are in-line with other reduced training frequency studies
296 that observed no apparent loss in maximum strength over periods of 1–32 weeks (2, 9, 10, 22, 23,
297 25). However, these findings of preserved maximum strength are in contrast with studies
298 investigating complete cessation of strength training that have observed decreases of 3–68% in
299 maximum strength over 1–24 weeks (6, 9, 10, 13, 14). Therefore, it is essential that older people do
300 not stop performing strength training, which is commonly observed in those new to strength training
301 (30). But ultimately, it appears that short-term (planned or unplanned) periods of reduced strength
302 training frequency throughout the year do not lead to loss of maximum strength in older individuals
303 and are of practical importance.

304

305 EMG amplitude of VL and VM increased significantly during the divergent frequency period (weeks
306 12–36). Although it is traditionally thought that neural adaptations occur early in a training
307 intervention and contribute to increased strength prior to observed increase in muscle mass (19),
308 the divergent frequency period was designed to increase the training load used during strength
309 training, which may be a key stimulant of the increased muscle activation. Recently, it has been
310 proposed that changes in surface EMG amplitude during a training intervention are largely
311 influenced by peripheral factors (7), such as altered propagation of action potentials (1). Perhaps the
312 changes in EMG amplitude observed in the present study do not reflect adaptations within the
313 central nervous system. Nevertheless, since both intervention groups demonstrated the same
314 increases in EMG amplitude during the divergent frequency period, it can be suggested that a

315 systematic adaptation to strength training occurred and that this is not affected by training
316 frequency.

317

318 Preserving muscle mass is an important issue for older individuals since well-functioning muscles
319 help to maintain movement and functional capacity as well as a healthier body composition. Age-
320 related loss of muscle mass in older women is highlighted in the results of the control group during
321 both periods in the present study (-3% in weeks 0-12 and then a further -3% in weeks 12-36). These
322 declines are of greater magnitude than the ones that are typically reported in research (i.e. 1%
323 decline per year). However, caution is advised in the interpretation of CSA at a single measurement
324 point, considering that it may not represent what is happening at the whole body/muscle level (15,
325 20, 24). Nevertheless, an important finding is that the initial training period (where both groups
326 trained twice-per-week) led to increased VL+VI CSA in both intervention groups (approximately 5%,
327 Figure 3), which was divergent from control. However, these initial improvements were reversed
328 when training once-per-week for the subsequent 24 weeks (-5%). Hence, while improved muscle
329 function was maintained during the period of reduced training frequency, muscle mass and its
330 potential health benefits were not. The observed reversal of training-induced gains in quadriceps
331 CSA in RST is in agreement with complete cessation studies, but our data disagree with that of the
332 two out of three studies investigating reduced training frequency on muscle mass (22, 23). Given the
333 lack of studies it is difficult to interpret these contrasting findings, but it may be that older women
334 are more susceptible to loss of muscle mass during reduced training frequency than men, since the
335 only study that included women (2) observed maintained strength but reduced muscle mass. It is
336 worth noting that the proportion of women to men was not mentioned in the study by Bickel et al.
337 (2).

338

339 The present study observed significant increase in total testosterone in both intervention groups.
340 This led to higher TT:C, TT:SHBG (so called free-androgen index) and TT:DHEA-S ratios since there
341 were no changes in other hormone concentrations. This might suggest that strength training has an
342 effect on the endocrine system in some way, and it appears that in previously untrained older
343 women this is observable regardless of training frequency. Our finding of increased basal TT is in
344 contrast with the findings of Häkkinen et al. (15) but in agreement with the findings of Kraemer et al.
345 (18) in older women. However, the increase in basal TT concentration was accompanied by an
346 increase in SHBG in the latter study, which did not occur in the present study. The exact cause of this
347 discrepancy is difficult to discern. However, the present study observed no change in body fat mass
348 (data not shown) or in basal insulin concentration, which has been shown to affect SHBG levels (17),
349 and these data were not reported by Kraemer and colleagues (18). Hence, the overall increase in TT
350 and the increased ratios may indicate a larger proportion of bioavailable testosterone in the present
351 study, although free testosterone concentration would be needed to confirm this. In this regard, it
352 may be viewed that a more positive and/or anabolic hormone profile was observed in the present
353 study. Ultimately, however, limited interpretation of the data can be made since the up-stream
354 regulators of TT (e.g. LH and FSH) were not measured to determine whether production likely
355 increased and also down-stream effectors were not measured to determine whether changes in
356 uptake (into liver and muscle) occurred.

357

358 One strength of this study was the use of an initial 12-week (preparatory) strength training period
359 prior to divergent training frequency. This allowed all previously untrained subjects to become
360 accustomed to strength training using low loads and reduce the influence of large improvements
361 expected at the beginning of a training program, hence, allowing better comparison of the divergent
362 training frequencies. Also, the intervention was supervised and progression was actively encouraged
363 by the researchers, therefore, we can be confident that the methods were controlled and maximized

364 any potential for adaptation. Weaknesses that may be improved upon in future research include; the
365 use of one measurement cite for CSA/hypertrophy determination, a lack of detailed investigation
366 into muscle activation, and the lack of additional functional measures, such as walking tests, to
367 determine whether these findings influence other aspects of daily function.

368

369 In conclusion, reduced training frequency does not adversely affect maximum strength, muscle
370 activity or hormonal profile in previously untrained older women. This is important information for
371 older individuals, as well as health and fitness professionals as it may encourage more older people
372 to engage in regular strength training and gives confidence to alter the individual's training program
373 to target specific training goals throughout the year. However, the present study also showed that
374 initial gains in muscle mass may be compromised and reversed when training once-per-week over
375 such a prolonged period.

376

377 PRACTICAL APPLICATIONS

378 This study shows that short-term periods of reduced training frequency do not negatively influence
379 gains in maximum strength and hormonal profile. This is likely different than completely stopping
380 strength training as previously discussed. Therefore, initiating and maintaining strength training at
381 least once-per-week is recommended. Furthermore, this knowledge may allow health and fitness
382 professionals to periodize long-term training programs in this population since periodic focus on
383 other specific training goals is possible (e.g. endurance or impact training for bone accrual etc.).
384 Nevertheless, reduced training frequency to once-per-week did negatively affect muscle mass as
385 noted by the quadriceps cross-sectional area results. Consequently, it is recommendable that a
386 higher training frequency would be restored when possible or other methods to maximize muscle
387 mass be used (e.g. nutritional intervention).

388 Importantly, this study has shown that low training frequency can bring about gains in older
389 individuals and this age-group should be encouraged to perform regular strength training at
390 whatever training frequency is possible/preferred. This should also be noted in national and
391 international physical activity guidelines, which may encourage a greater number of older individuals
392 to initiate and continue strength training.

393

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487 FIGURE LEGENDS

488 Figure 1. Leg press 1-RM load (mean±SD) throughout the study (A) and relative changes (Δ%;
489 mean±SD) during the divergent training frequency period. RST = Reduced Strength Training group,
490 ST = Strength training group, CON = control group. ‡=P<0.05 compared to week 0, *=P<0.05
491 compared to week 12. Note: for clarity there are no SD bars for the control group.

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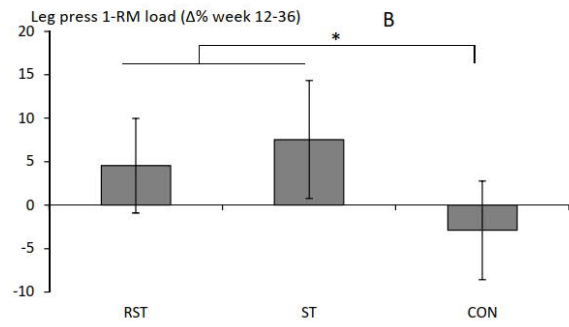
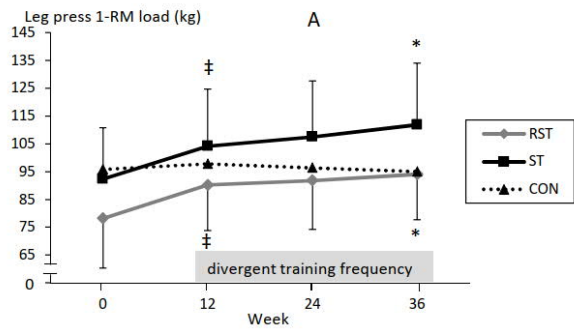
493 Figure 2. Concentric quadriceps EMG amplitude load (mean±SD) during leg press 1-RM throughout
494 the study (A) and relative changes (Δ%; mean±SD) during the divergent training frequency period.
495 RST = Reduced Strength Training group, ST = Strength training group, CON = control group. ‡=P<0.05
496 compared to week 0, *=P<0.05 compared to week 12. Note: for clarity there are no SD bars for the
497 control group.

498

499 Figure 3. Quadriceps cross-sectional area load (mean±SD) throughout the study (A) and relative
500 changes (Δ%; mean±SD) during the divergent training frequency period. RST = Reduced Strength
501 Training group, ST = Strength training group, CON = control group. ‡=P<0.05 compared to week 0,
502 *=P<0.05 compared to week 12. Note: for clarity there are no SD bars for the control group.

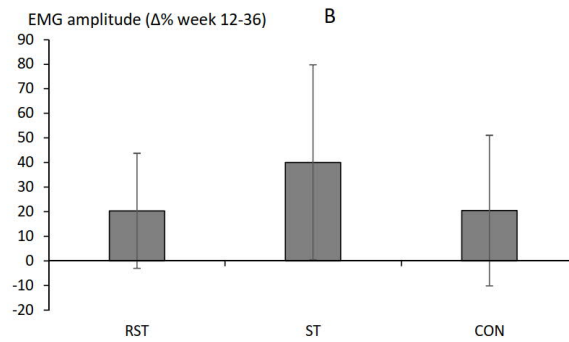
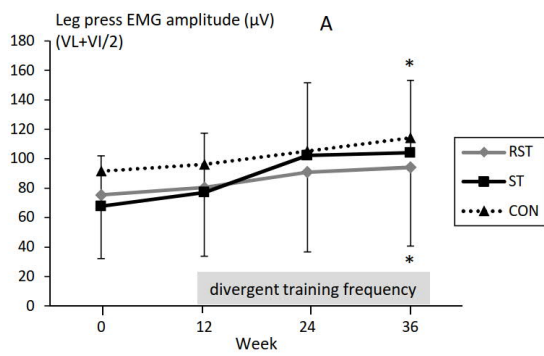
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Figure 1



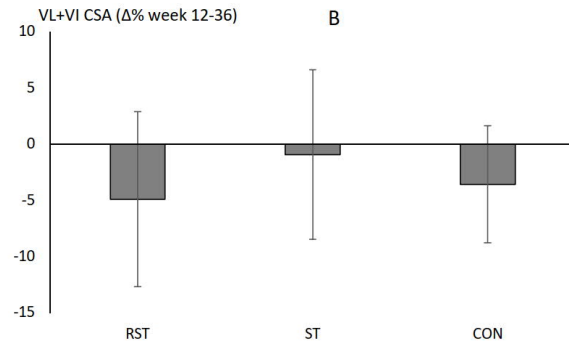
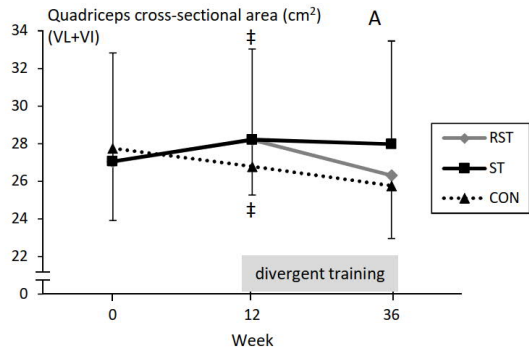
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Figure 2



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Figure 3



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