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

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

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ABSTRACT

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

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

INTRODUCTION

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

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

Despite this potentially important information, few studies have investigated the effect of reduced frequency strength training on strength and muscle mass. Tapering in athletes is an accepted form of competition preparation and at least short-term (i.e. 1–4 weeks) reduced training volume appears not to adversely affect performance (9, 16). Nevertheless, reduced training frequency in recreationally active populations can last several weeks/months. The few studies that have investigated reduced training frequency demonstrate that strength (10, 25) and muscle mass (2, 23) can be maintained over relatively long periods with as little as one training session per week.

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

METHODS

Experimental approach to the problem

Two groups of older women performed whole-body strength training twice-per-week for 12 weeks. Thereafter, one group continued training twice-per-week (ST) while the other group reduced their strength training frequency to once-per-week (RST) for a further 24 weeks. A third group maintained their normal physical activity habits over the total 36-week period and acted as a non-training control group. Measures of maximum dynamic strength with accompanying surface electromyography (EMG), muscle mass and basal hormone concentrations were performed before training (week 0), after the initial strength training period (week 12) and after the divergent frequency strength training period (week 36). Also, maximum dynamic strength was assessed in the two intervention groups after 24 weeks of training (i.e. in the middle of the divergent frequency training period).

Subjects

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

Maximum dynamic strength

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

Surface electromyography

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

Quadriceps cross-sectional area

Cross-sectional area (CSA) measurements of VL and vastus intermedius (VI) of the right leg were taken 1-2 days prior to dynamic leg press performance tests and 6-7 days after the final training session to account for any exercise-induced swelling. CSA was assessed by B-mode ultrasound (model SSD-α10, Aloka Co Ltd, Tokyo, Japan) using a 10 MHz linear-array probe (60 mm width) coated with water-soluble transmission gel with the extended-field-of-view mode (23 Hz sampling frequency). This method has been used during several training studies (28, 29). Indelible ink tattoos on the medial and lateral sides of the target muscles ensures accurate replacement of scanning track. Oriented in the axial-plane, the probe was moved manually with a slow and continuous movement from medial to lateral along a marked line on the skin. Great care was taken to diminish compression of the muscle tissue. Images were obtained throughout the movement. As the orientation of each image relative to adjacent images is known, the software builds a composite image. Four panoramic CSA images were taken at 50% femur length from the lateral aspect of the distal diaphysis to the greater trochanter. Upon visual inspection of the composite images three were selected to undergo further analysis. CSA was determined by manually tracing along the border of each muscle using Image-J software (version 1.37, National Institute of Health, USA). The mean of the two closest values for each muscle were taken as the CSA result and then the sum of the two muscles (VL+VI) was taken as the final value. Combined VL+VI test-retest reliability was ICC r=0.926, CV%=4.0%. The same researcher performed the data acquisition and analyses.

Serum hormone concentrations

Basal blood samples (5 ml whole blood into Venosafe serum-separator tubes: Terumo Medical Co, Leuven, Belgium) were obtained from an antecubital vein following an overnight fast (12 h) between the hours of 7-9am. Samples stood at room temperature for 15 min and then were centrifuged for 10 min (3500 rpm at 4°C, Megafuge 1.0R, Heraeus, Germany). Serum samples were stored at -80°C until the completion of the study and then analyzed for total testosterone (TT), sex-hormone binding globulin (SHBG), cortisol (C), dehydroepiandrosterone sulfate (DHEA-S) and insulin using immunometric chemiluminescence techniques (Immulite 2000, Siemens, Illinois, USA) with hormone-specific immunoassays. In all cases, a pre-standard is analyzed to ensure that kits are detecting within the required range, then single samples are run, any potential erroneous values are checked and if necessary run in duplicate (and possibly also triplicate). Analytical sensitivity (nmol·L^{-1}) and reliability (CV%) were 0.5 and 13%, 0.02 and 5.2%, 5.5 and 7.3% for TT, SHBG and C, respectively.

Strength training program

The training groups performed whole-body strength training twice-per-week for 12 weeks with at least 48 hours between sessions and each session was supervised by experienced gym instructors. All exercises were performed on commercially available strength machines (Precor Vitality SeriesTM, Precor Inc, UK). Exercises included leg press, knee extension, knee flexion, chest press, lat pulldown, shoulder press, seated row, bicep curl, triceps pushdown, ab curl and back extension. The 12-week program was divided into a 4-week initiation phase (1min inter-set rest) and an 8-week super-set training phase. Super-sets were: 1) Leg press+chest press, 2) knee extension+lat pulldown, 3) knee flexion+triceps pushdown, 4) ab curl+back extension in session 1 and 1) Leg press+seated row, 2) knee extension+shoulder press, 3) knee flexion+biceps curl, and 4) ab curl+back extension in session 2, with 1min rest between sets. The primary goal of this initial training period was to teach the subjects correct technique for all exercises and to progressively increase the loads and reduce the rest periods so that local muscular endurance was improved. Intensity for all upper and lower limb exercises was approximately 50–60% of estimated 1-RM. All subjects were required to perform all repetitions using a tempo of 2s concentric and 2s eccentric phase and at least 1 set should be performed to concentric failure before completing the maximum number of allocated repetitions. Repetition ranges used during the initiation phase was 16-20 and 14-16 during the super-set phase. Whenever the subjects could perform the maximum number of allocated repetitions during all sets without concentric failure the load was increased during the next session. The training groups then continued to perform whole-body strength training at a frequency of either once- (RST) or twice- (ST) per-week for 24 weeks (weeks 13–36) on non-consecutive days. This 24-week period was divided into two 12-week mesocycles. The primary goal of mesocycle 1 was to increase maximum strength and muscle mass. The primary goal of mesocycle 2 was to increase maximum strength and power. Intensity for all upper and lower limb exercises was approximately 70–90% 1-RM with power training performed using 30-80% 1-RM loads but maximum concentric velocity. Multiple sets (2-5) were performed with repetition ranges of 4-12 and inter-set rest of 1-3min depending on the training goal. All subjects were required to perform at least 1 set to concentric failure with the exception of power training. All subjects were required to complete at least 90% of all allocated training sessions prior to testing. The non-training control group was instructed to maintain their normal physical activity throughout the study period.

Statistical analyses

All data were presented as means and standard deviations (±SD). All statistical methods were performed using IBM SPSS statistics 24 software. The Shapiro-Wilk test was used to test normality and Levene’s test was used to analyze homogeneity of variance. Baseline differences for all parameters were tested by means of one-way analysis of variance. Difference testing was performed using repeated measures analysis of variance (ANOVA: 3 group × 3 time) and Bonferroni post hoc tests were performed whenever a significant group×time interaction was observed. EMG data was assessed by within-group repeated measures ANOVA with Bonferroni post hoc tests between time points since the amplitude of the EMG signal cannot be compared between subjects. Effect sizes (Hedges' g) were calculated for the differences in relative change (from week 13 to 36; i.e. before and after the divergent frequency training period) between the intervention and control groups, where small (<0.3), medium (0.3–0.8), and large (>0.8) effect sizes were identified. Statistical significance was accepted when P<0.05.

RESULTS

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

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

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

A statistically significant group×time interaction was observed in summed CSA (VL+VI) (F=3.7, P=0.019). CSA increased in both intervention groups during the initial strength training period (RST: P=0.072, 95%CI=-0.3–5.2cm^2, ST: P=0.031, 95%CI=0.9–2.3cm^2, Figure 3). Thereafter, no changes occurred in the group training twice-per-week, but a trend of decreased CSA was observed in the group training once-per-week (P=0.065, 95%CI=-2.9–0.8cm^2) without between-group differences. No changes occurred in the control group.

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

DISCUSSION

The present study showed that reduction of training volume to once-per-week did not adversely influence improvements in leg press 1-RM in previously untrained older women undergoing supervised training. It should be noted that although the divergent frequency training period followed an initial 12-week training period, the potential for 1-RM improvement in this group of subjects was still large in this group of previously untrained individuals. In addition, potentially positive alterations in serum hormone profile were observed, and these alterations were independent of training frequency. Otherwise, it appears that the initial increases in muscle mass could not be maintained during a prolonged period of training once-per-week. This is a major finding of this study since combating age-related loss in muscle mass is a primary goal of strength training in this age group.

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

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

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

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

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

One strength of this study was the use of an initial 12-week (preparatory) strength training period prior to divergent training frequency. This allowed all previously untrained subjects to become accustomed to strength training using low loads and reduce the influence of large improvements expected at the beginning of a training program, hence, allowing better comparison of the divergent training frequencies. Also, the intervention was supervised and progression was actively encouraged by the researchers, therefore, we can be confident that the methods were controlled and maximized any potential for adaptation. Weaknesses that may be improved upon in future research include; the use of one measurement cite for CSA/hypertrophy determination, a lack of detailed investigation into muscle activation, and the lack of additional functional measures, such as walking tests, to determine whether these findings influence other aspects of daily function.

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

PRACTICAL APPLICATIONS

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

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

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FIGURE LEGENDS

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

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

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

Figure 1

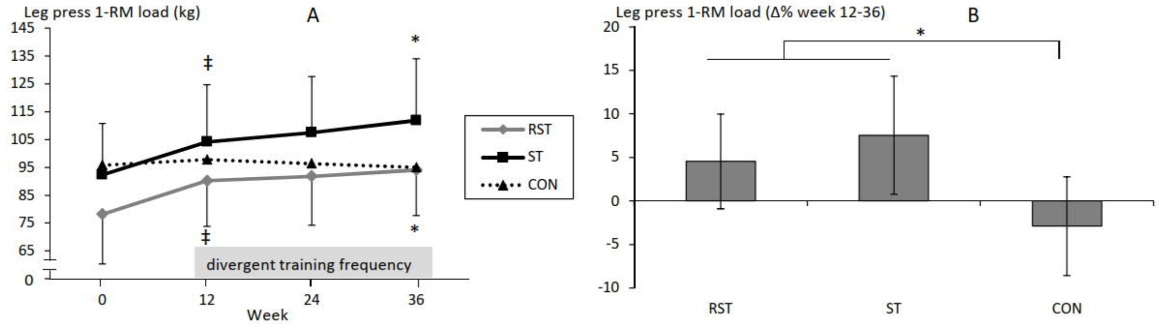

Figure 2

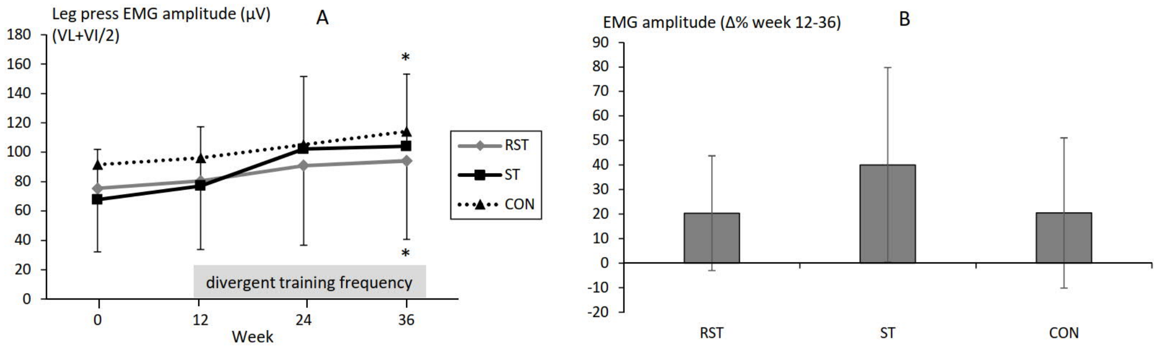

Figure 3