INDIVIDUAL MUSCLE HYPERTROPHY AND STRENGTH RESPONSES TO HIGH VS. LOW RESISTANCE TRAINING FREQUENCIES

FELIPE DAMAS,1 CINTIA BARCELOS,1 SANMY R. NÓBREGA,1 CARLOS UGRINOWITSCH,2 MANOEL E. LIXANDRÃO,2 LUCAS M. E. D. SANTOS,1 MIGUEL S. CONCEIÇÃO,2 FELIPE C. VECHIN,2 AND CLEITON A. LIBARDI1

1MUSCULAB—Laboratory of Neuromuscular Adaptations to Resistance Training, Department of Physical Education, Federal University of São Carlos—UFSCar, São Carlos, São Paulo, Brazil; and 2School of Physical Education and Sport, University of São Paulo—USP, São Paulo, São Paulo, Brazil

ABSTRACT

Damas, F, Barcelos, C, Nobrega, SR, Ugrinowitsch, C, Lixandrao, ME, Santos, LMed, Conceicao, MS, Vechin, FC, and Libardi, CA. Individual muscle hypertrophy and strength responses to high vs. low resistance training frequencies. J Strength Cond Res XX(X): 000–000, 2018—The aim of this short communication was to compare the individual muscle mass and strength gains with high (HF) vs. low (LF) resistance training (RT) frequencies using data from our previous study. We used a within-subject design in which 20 subjects had one leg randomly assigned to HF (5× per week) and the other to LF (2 or 3× per week). Muscle cross-sectional area and 1 repetition maximum were assessed at baseline and after 8 weeks of RT. HF showed a higher 8-week accumulated total training volume (TTV) (p < 0.0001) compared with LF. Muscle cross-sectional area and 1 repetition maximum values increased significantly and similarly for HF and LF protocols (p > 0.05). This short communication highlights that some individuals showed greater muscle mass and strength gains after HF (31.6 and 26.3% of individuals, respectively), other had greater gains with LF (36.8 and 15.8% of individuals, respectively), and even others showed similar responses between HF and LF, regardless of the consequent higher or lower TTV resulted from HF and LF, respectively. Importantly, individual manipulation of RT frequency can improve the intra-subject responsiveness to training, but the effect is limited to each individual’s capacity to respond to RT. Finally, individual response to different frequencies and resulted TTV does not necessarily agree between muscle hypertrophy and strength gains.

KEY WORDS individual responsiveness, total training volume, 1 repetition maximum, muscle cross-sectional area

INTRODUCTION

Resistance training (RT)-induced increases in muscle mass (i.e., hypertrophy) and strength have significant impact in overall health, diseases prevention (29), and athletic performance (2). The effect of RT weekly frequency on muscle hypertrophy and strength development has been given special attention lately (6,12,14,16,25,30). The rationale for examining the impact of different frequencies on RT outcomes relies on recent studies showing the time course of increases in muscle protein synthesis after RT session (lasting ~24–48 hours after an RT session) (10,11,28). In addition, higher RT frequencies could result in greater training volumes, which in turn would positively affect muscle hypertrophy and strength gains (16,26).

Notwithstanding, our group recently showed that performing RT 2, 3, or 5 times per week resulted in similar gains in muscle hypertrophy and strength after 8 weeks in untrained individuals, even with a higher 8-week accumulated total training volume (TTV) for the higher frequency (sets × reps × load) (3). Other reports also showed similar RT outcomes after distinct RT frequencies both in untrained and trained individuals, irrespectively of matching TTV (4,6,8,14). However, these findings are not universal, especially when higher training frequencies result in greater TTV (16,25,30). These discrepancies could be due, at least in part, to interindividual differences in responsiveness to distinct RT frequencies. A large variability has been reported for muscle strength and hypertrophy outcomes even when subjects perform standardized RT programs (1,9,20). However, no study has evaluated the effects of manipulation of RT frequency within the same individual.
The present short communication compared individual muscle hypertrophy and strength gains with high (HF, 5× per week) vs. low (LF, 2 or 3× per week) RT frequencies in the same subjects (unilateral design) over 8 weeks of RT using data from our previous study (3). We hypothesized that the intersubject variability would be high, but a per-individual analysis would show that most of the subjects would respond better to the high RT frequency, as it results in greater TTV over the training period.

METHODS

Experimental Approach to the Problem
This is a follow-up short communication to analyze individual responses to HF (RT performed 5× per week) and LF (RT performed 2 or 3× per week) from our previous publication (3). In short, a within-subject approach was used in which each subject performed RT after an HF with one leg and an LF with the other leg. Subject’s legs were randomly allocated in 1 of the 2 experimental protocols in a counterbalanced way. Specifically, one leg of each subject was allocated in the HF (10 dominant and 10 nondominant legs), and the contralateral legs were then randomized in LF (10 dominant [5 in each low frequency, i.e., 2 or 3× per week] and 10 nondominant legs [5 in each low frequency]). The vastus lateralis muscle cross-sectional area (CSA) was assessed using ultrasound and the maximum dynamic strength by a unilateral 1 repetition maximum (1RM) test, both before and after 8 weeks of RT.

Subjects
The subjects included in this short communication were the same from our previous article (3) (young untrained men, mean ± SD: n = 20, 23 ± 4 years [18–30 years old]; 174 ± 6 cm; 72 ± 8 kg). However, one participant was excluded from the analyses because he did not complete the experiment protocol because of personal reasons. The study was approved by the Federal University of São Carlos Ethic Committee, and each participant signed informed consent before participation. All procedures performed in the study were in accordance with the ethical standards of the institutional research committee and with the Helsinki declaration.

Procedures

Muscle Cross-Sectional Area and Maximal Dynamic Strength (1 Repetition Maximum). Vastus lateralis muscle CSA was assessed using sequential images acquired by a B-mode ultrasound with a 7.5-MHz linear probe (MySono U6; Samsung, São Paulo, SP, Brazil) and an image-fitting technique that our group has validated previously (23). Maximal dynamic strength was assessed using the 1RM test on the leg extension machine following previously described criteria (7).

Resistance Training. All RT protocols were performed in a leg extension machine (Effort NKR; Nakagym, Diadema, SP, Brazil). Training protocol consisted of 3 sets of 9RM–12RM to muscular failure. A 2-minute rest interval was allowed between sets because it was showed to be sufficient to promote increases in muscle hypertrophy (15) and strength in untrained individuals (17). Total training volume was calculated as sets × repetitions × load (kg).

Statistical Analyses
For the analyses, each leg (experimental unit) was grouped into either an HF (legs previously allocated to the 5× per week RT) or LF (legs previously allocated to 2 or 3× per week RT) (3). For group analyses, the accumulated TTV and changes in muscle CSA and 1RM values were compared between HF and LF using paired t-tests. For individual analyses, if an individual that showed a difference in the response (for CSA or 1RM increases) from HF or LF (or vice versa) within 2 typical errors (CSA typical error = 1.38%, 1RM typical error = 3.64%; values extracted from Ref. 3), no difference in the response between RT frequencies was considered. Relationships between variables were assessed using the Pearson’s correlation. In addition, we defined an individual as “responder” to RT as one with a response greater than 2 typical errors from zero for increases in muscle CSA and 1RM; if not, he was considered as “nonresponder” (19). A chi-square test was performed to compare the proportion of individuals (responders) that had higher CSA and 1RM gains (greater than 2 typical errors) after training between HF and LF. In case of significant ρ values, standard residuals were analyzed to determine which proportions were significantly different in the contingency table. Differences in the estimated proportions were considered significantly different if standard residuals were outside the interval [−2, 2]. Significance was established as ρ ≤ 0.05.

RESULTS

Total Training Volume, Changes in Muscle Cross-Sectional Area, and 1 Repetition Maximum
Group analyses showed that HF resulted in higher 8-week accumulated TTV (ρ < 0.0001) compared with LF (Figure 1A). However, similar changes were found in CSA and 1RM changes comparing legs that trained at HF vs. LF (ρ > 0.05; Figure 1B, C, respectively).

The individual analyses showed that all subjects depicted higher TTV for HF vs. LF (Figure 1A). For muscle hypertrophy, 6 individuals (31.6% of the sample) responded more HF, 7 individuals (36.8% of the sample) responded more for LF, and the other 6 individuals (31.6% of the sample) showed no difference in the hypertrophic responses between training frequencies (the difference was within 2 typical errors) (Figure 1B). Regarding muscle strength, 5 individuals (26.3% of the sample) increased more the 1RM value for HF, 3 (15.8% of the sample) for LF, and the other 11 (57.9% of the sample) showed similar responses between RT frequencies (Figure 1C). No significant correlations were found between TTV and CSA (ρ = 0.59; r = 0.09) or 1RM (ρ = 0.17; r = 0.22). Importantly, after manipulation of the RT frequency (i.e., HF-to-LF or LF-to-HF), only one
individual (marked as “white upside-down triangle”) was still considered “nonresponder” for muscle hypertrophy. For muscle strength, after RT frequency manipulation, no individual was still considered a “nonresponder.” The chi-square test showed that there were no significant differences between the proportion of individuals who become responders after HF or LF for both CSA and 1RM gains ($p > 0.05$).

**DISCUSSION**

This is the first study to analyze individual responses to different RT frequencies. As hypothesized, our results showed a large intersubject variability to HF and LF, but contrarily to what we proposed, most subjects did not show greater responses (muscle hypertrophy and strength) to the RT frequency that resulted in a larger TTV.

Our unilateral RT protocol elaborated to minimize between-subject variability, allowed to compare the leg that performed an HF (RT 5× per week) with the contralateral leg, which performed an LF (RT 2 or 3× per week). In accordance with our previous article (3), group analyses showed higher TTV for HF (Figure 1A), but similar hypertrophic (Figure 1B) and muscle strength (Figure 1C) outcomes between HF and LF. An interesting hypothesis is that there might exist a training volume threshold beyond which there is no further increase in muscle mass and strength, as discussed in more detail recently (13). In fact, the individual analyses demonstrate that a significant proportion of subjects showed no difference in their responses manipulating RT frequency (31.6% of the subjects for muscle hypertrophy and 57.9% for muscle strength). Even so, some individuals greatly increased the muscle CSA and 1RM values in response to an HF, but, surprisingly, other responded better to LF, despite all subjects had greater TTV after HF (Figure 1). Corroborating with the results above, when RT frequency is manipulated, we report no correlation between TTV and CSA or 1RM increases. These results do not fully support the hypothesis that the magnitude and duration of elevated muscle protein synthesis in response to RT bout and the greater accumulated TTV would favor training muscles with a greater frequency. Specifically, for muscle hypertrophy, ~31.6% of the sample responded more for HF, and for muscle strength, ~26.3% of the sample benefited more from HF. We suggest that some individuals might be “less sensitive” to RT stimulus, requiring a higher RT frequency (or TTV) to maximize their RT-induced adaptations. Some studies with endurance training indicate that individuals considered as low responders (e.g., have small or no increase in maximal oxygen consumption [$V_{O2max}$]) may better respond to higher training volumes (18,27). The same concept does not seem to hold for RT, as some subjects (36.8% for muscle hypertrophy and 15.8% for muscle strength) in this study were more responsive to LF (and consequent smaller TTV). These results could indicate that these subjects might require a longer time to recover between sessions or even that they are more sensitive to inhibitory mechanisms of hypertrophy and strength gains performing larger weekly TTV. These suggestions require further investigation. In addition, we expand the TTV threshold hypothesis, indicating that should it really exists, it is to some extent individual-dependent, and further increases in TTV can even impair muscle mass and strength development with RT in some individuals.

![Figure 1](image-url)

*Figure 1. A) Individual 8-week accumulated total training volume (TTV, sets × reps × load [kg]), % changes in (B) muscle cross-sectional area (CSA) and (C) 1 repetition maximum (1RM) at week 8 relative to baseline for high and low resistance training frequencies. Pointed lines in panels (B) and (C) indicate “zero” value, and dashed lines indicate “cut-points” for responsiveness: 2.76% for CSA and 7.28% for 1RM (see Methods for details). *Significant difference from lower resistance training frequencies ($p < 0.0001$).*
Individual Responses to Training Frequencies

Interestingly, 3 subjects (of 19) were considered as “nonresponders” for muscle hypertrophy considering HF and LF separately, but only 1 subject was considered a “nonresponder” after the manipulation of RT frequency (HF-to-LF or LF-to-HF) (Figure 1B). For muscle strength, also 3 subjects were considered as “nonresponders” after HF or LF separately, but all were considered as “responders” when RT was manipulated (Figure 1C). However, it should be highlighted that despite the manipulation of RT frequency can alter intraindividual responsiveness to RT, the interindividual responses are dependent on each individual’s genetic predisposition to respond to RT. Other factors as nutritional patterns, daily activities, etc., could also have an impact on intersubject responsivity to RT. Our data show that some individuals presented greater responses in comparison with other subjects irrespectively of RT frequency, i.e., even the smallest increase that some subjects achieved was still higher than the largest increase of other. Overall, the individual manipulation of RT frequency is relevant because it can improve the intraindividual responsiveness to training, but the effect is limited to each individual capacity to respond to RT.

It should also be noted that the intraindividual muscle hypertrophy and strength responses were not aligned between RT frequencies, i.e., a given individual can show a better hypertrophic response to HF, but increase more muscle strength for LF (or vice versa, Figure 1). Our results showed that only 6 of 19 subjects (~32% of our sample size) showed an aligned response for muscle strength and hypertrophy after the same RT frequency (whether HF or LF). This suggests that the biological mechanisms regulating individual responsivity to different RT frequencies regarding muscle strength and mass gains are distinct. Future studies should investigate the individual’s biological mechanisms behind the effect of manipulations of RT variables, as it is plausible to consider that not only frequency and TTV, but also load, muscle actions, repetition duration, and rest, for example, could modulate individual responsiveness to muscle hypertrophy and strength adaptations.

Importantly, the results of this study can be specific to previously untrained young men performing RT for 8 weeks. Both sex and age could alter the effect of training frequency because of differences in fatigability, time to recover from training, and required RT weekly dose (5,21,22). It is also possible that longer RT periods and the use of previously trained subjects could modulate the individual responses to distinct RT frequencies. Trained individuals depict a shorter increase in muscle protein synthesis (10), and longer training periods (e.g., 6 months) was showed to result in a dosed response of weekly training volume in muscle hypertrophy (24). Thus, it is possible that trained individuals, in general, would require more frequent training stimulus (and maybe higher weekly volumes), decreasing interindividual variability as subjects become more trained. These speculations require further scrutiny. In addition, the use of unilateral exercise was specifically chosen to evaluate the intraindividual variability to distinct RT frequencies performed during the same time frame (i.e., 8 weeks), but other research are commended to investigate this research question using, e.g., bilateral exercises and a wash-out period. Also, upper-body and additional exercises could be tested, as maybe a different pattern of response could emerge.

In conclusion, this short communication highlights that interindividual variability to different RT frequency (and consequent TTV) is high, and, surprisingly, some individuals showed greater muscle hypertrophy and strength gains after lower RT frequencies, which resulted in lower TTV. Importantly, intraindividual responsiveness to training can be modulated through the manipulation of RT frequency; however, the effect is limited to each individual’s capacity to respond to RT. Finally, the individual response to different frequencies and resulted TTV does not necessarily agree between distinct RT-related outcomes (i.e., muscle hypertrophy and strength gains).

**Practical Applications**

Considering individual responses, some subjects respond better after a higher RT weekly frequency and consequent accumulated RT volume, others might benefit more from lower RT weekly frequencies and accumulated RT volume, and even others show similar responses irrespective of RT frequency manipulation. Importantly, this occurred despite the fact that previously untrained subjects were studied in the present investigation, challenging the notion (based on average group values) that any training scheme maximally stimulates RT-related outcomes in this population. In addition, manipulation of RT frequency has an impact on intraindividual responsiveness to training, but this effect is limited to the each individual’s capacity to respond to RT. Finally, care should be taken on which RT outcome (e.g., muscle hypertrophy or strength) should be the training focus, as individual responsiveness to different RT outcomes may differ among RT frequencies and volumes chosen.

**Acknowledgments**

This work was supported by the São Paulo Research Foundation (FAPESP) (#2016/24259-1 to F.D., #2016/22635-6 to M.E.L., and #2013/21218-4 and #2017/04299-1 to C.A. L.) and the National Council for Scientific and Technological Development (CNPq) (#406609/2015-2 to C.U.) grants.

**References**


