Training Volume, Not Frequency, Indicative of Maximal Strength Adaptations to Resistance Training

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Abstract

Colquhoun, RJ, Gai, CM, Aguilar, D, Bove, D, Dolan, J, Vargas, A, Couvillion, K, Jenkins, NDM, and Campbell, BI. Training volume, not frequency, indicative of maximal strength adaptations to resistance training. *J Strength Cond Res* 32(5): 1207–1213, 2018—To compare the effects of a high versus a moderate training frequency on maximal strength and body composition. Twenty-eight young, healthy resistance-trained men were randomly assigned to either: 3× per week (3×; $n = 16$) or 6× per week (6×; $n = 12$). Dependent variables (DVs) assessed at baseline and after the 6-week training intervention included: squat 1 repetition maximum (SQ1RM), bench press 1RM (BP1RM), deadlift 1RM (DL1RM), powerlifting total (PLT), Wilk's coefficient (WC), fat-free mass (FFM), and fat mass. Data for each DV were analyzed using a 2 × 2 between-within factorial repeated-measures analysis of variance. There was a main effect for time ($p < 0.001$) for SQ1RM (3×: +16.8 kg; 6×: +16.7 kg), BP1RM (3×: +7.8 kg; 6×: +8.8 kg), DL1RM (3×: +19 kg; 6×: +21 kg), PLT (3×: +43.6 kg; 6×: +46.5 kg), WC (3×: +27; 6×: +27.1), and FFM (3×: +1.7 kg; 6×: +2.6 kg). There were no group × time interactions or main effects for group. The primary finding was that 6 weeks of resistance training led to significant increases in maximal strength and FFM. In addition, it seems that increased training frequency does not lead to additional strength improvements when volume and intensity are equated. High-frequency (6× per week) resistance training does not seem to offer additional strength and hypertrophy benefits over lower frequency (3× per week) when volume and intensity are equated. Coaches and practitioners can therefore expect similar increases in strength and lean body mass with both 3 and 6 weekly sessions.

Key Words muscular strength, hypertrophy, periodization, powerlifting

Introduction

Resistance training is an important facet in maintaining skeletal muscle mass and muscular strength. As such, there has been a great deal of research into the programming and manipulation of resistance training variables (i.e., volume, intensity, etc.). To date, much of the resistance training research has focused on the manipulation of volume, intensity, and rest interval, leading to a general consensus within the scientific literature on these topics. For example, it is widely accepted that volume plays a key role in both strength and hypertrophic adaptations (22,25,26). In addition, it has been shown that skeletal muscle hypertrophy can occur across a variety of training loads (16,18), whereas longer rest intervals lead to increased hypertrophy and strength over shorter rest intervals (7). However, a paucity of research exists regarding strength training frequency, leading to widespread debate over the optimal frequency of resistance training for strength and hypertrophy.

Resistance training frequency can be defined as number of sessions performed or the number of times a muscle group is trained within a period (28). For the context of this investigation, frequency was defined as the number of training sessions completed within a week. It has been suggested that as resistance training experience increase, there should be a concomitant increase in training frequency (19). Anecdotally, this increase in training frequency may have physiological and psychological benefits. For example, many high-level weightlifters split their daily training volume into 2 training sessions, especially during periods of high training volume, in an attempt to maintain intensity (8). Although

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32(5)/1207–1213

Journal of Strength and Conditioning Research

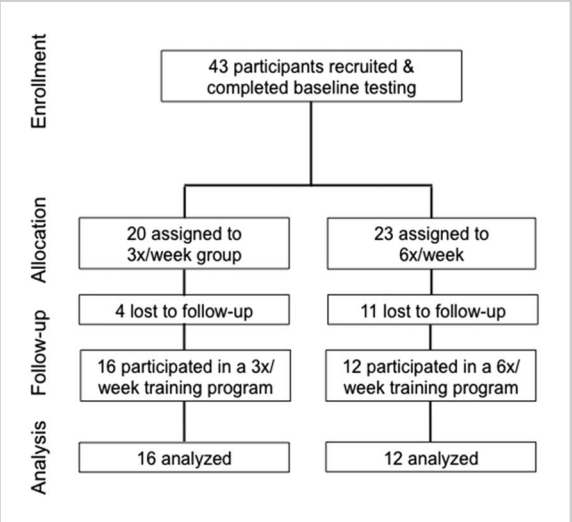

Figure 1. Participant flow. 3x/week = frequency of 3 times per week of resistance training. 6x/week = frequency of 6 times per week of resistance training.

anecdotal evidence favoring increased training frequency exists, the amount of peer-reviewed scientific data is lacking.

To date, most of the studies comparing different resistance training frequencies have used untrained subjects (1,2,10). In addition, most of these studies have shown no additional benefit to an increased training frequency, with most of the data showing equal strength and hypertrophic adaptation between low- and high-frequency groups (1,2,10). Interestingly, in one of the only studies using trained subjects, McLester et al. (21) showed that a training frequency of 1× per week leads to 62% of the strength gains experienced by a group that resistance trained 3× per week. These results are in line with a recent investigation using trained subjects by Schoenfeld and et al. (29) who showed significantly greater increases in forearm flexor thickness in a group that trained with a whole-body (3× per week) resistance training program, as compared to a split (1× per week) group. It, therefore, may be inferred that training frequency plays a more important role in the strength and hypertrophic adaptation of trained individuals. However, to the best of the authors' knowledge, no study has examined the effects of high-frequency (>3× per week) resistance training in trained subjects.

Therefore, the purpose of this study was to examine the effects of high-frequency (6× per week) resistance training versus a traditional resistance training frequency (3× per week) on maximal strength and body composition changes in resistance-trained men. We hypothesized that an increased training frequency would not lead to further improvements in strength and body composition when compared with a lower training frequency of volume- and intensity-matched resistance training.

Methods

Experimental Approach to the Problem

The study used a randomized, counterbalanced, parallel-groups design. Specifically, all subjects completed 1 repetition maximum (1RM) testing and body composition assessments (described below). Because the primary interest of the study was maximal strength outcomes, subjects were ordered based on Wilk's coefficient (WC), which has been previously validated as an objective measure of relative strength (32). A coin was then flipped to randomly assign the first subject to either the 3× group or the 6× group. The next 2 subjects were then assigned to the opposite group and this process was repeated until all subjects were randomly assigned to a respective group.

Subjects

Subjects in the present investigation were college-aged men (age range: 18 to 30 years) who were actively participating in resistance training for a minimum duration of 6 months (minimum of 3 days per week) before enrollment and regularly (i.e., average frequency ≥1× per week for each lift) included the powerlifts in their training program. In addition, subjects had to possess a back squat 1RM of 125% of their bodyweight, a bench press 1RM of 100% of their bodyweight, and a deadlift 1RM of 150% of

Table 1. Resistance training program, as represented by sets × reps for each of the main lifts.*

	Squat		Bench press		Deadlift	
	3×	6×	3×	6×	3×	6×
Monday	4 × 8	2 × 8	4 × 8	2 × 8		
Tuesday		2 × 5		2 × 5		
Wednesday	4 × 5	2 × 3	4 × 5	2 × 3		2 × 3
Thursday		2 × 8		2 × 8		
Friday	4 × 3+	2 × 5	4 × 3+	2 × 5	4 × 3+	
Saturday		2 × 3+		2 × 3+		2 × 3+

*+ Autoregulated progressive resistance exercise sets completed.

Table 2. Maximal strength and body composition data from pretesting to posttesting in both groups.*

	3× per wk			6× per wk		
	Pretesting	Posttesting	% Change†	Pretesting	Posttesting	% Change
Squat 1RM (kg)	136.8 ± 33.3	153.6 ± 33.7‡	12.2	139.1 ± 28.3	155.8 ± 23.5‡	12.0
Bench press 1RM (kg)	101.4 ± 18.9	109.2 ± 20.0‡	7.7	102.3 ± 28.1	111.1 ± 29.6‡	8.6
Deadlift 1RM (kg)	160.5 ± 37.1	179.5 ± 36.3‡	11.8	166.2 ± 33.2	187.2 ± 29.2‡	12.6
Powerlifting total (kg)	398.7 ± 84.4	442.3 ± 85.3‡	10.9	407.6 ± 86.5	454.1 ± 78.9‡	11.4
Wilk's coefficient	282.3 ± 44.8	309.3 ± 43.0‡	9.6	270.5 ± 44.4	297.6 ± 40.8‡	10.0
Fat-free mass (kg)	69.2 ± 13.5	70.9 ± 13.6‡	2.5	71.8 ± 7.5	74.4 ± 7.7‡	3.6
Fat mass (kg)	10.0 ± 6.6	9.7 ± 6.1	−3.0	12.3 ± 3.8	12.2 ± 3.7	−0.8

*1RM = 1 repetition maximum.
†Percentage change from pretesting to posttesting.
‡Significant difference from baseline testing.

their bodyweight. Forty-three subjects were initially enrolled in the study, with 28 subjects completing the entire duration of the study and used in the data analysis (Figure 1). A counterbalanced design was used to randomly assign subjects to 1 of 2 groups: 3× per week training frequency (± *SD* 3×; $n = 16$; age: 22 ± 2 years; body mass: 79.1 ± 18.9 kg) or 6× per week training frequency (6×; $n = 12$; age: 22 ± 3 years; body mass: 83.9 ± 9.0 kg). All subjects signed a written informed consent and voluntarily agreed to participate in this study, which was approved by the institutional review board of the University of South Florida, in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Table 3. Mean change scores, between groups' effects sizes, and 95% confidence intervals for the 3× per week and 6× per week groups.*

	Change score				95% confidence interval			
	3×	6×	ES	Favors	3×		6×	
Squat 1RM (kg)	16.7 ± 8.8	16.6 ± 12.5	0.01	3×	12.37	21.08	8.66	24.60
Bench press 1RM (kg)	7.8 ± 5.1	9.7 ± 6.8	0.31	6×	5.25	10.34	5.35	13.95
Deadlift 1RM (kg)	19.0 ± 11.7	21.0 ± 13.1	0.16	6×	13.18	24.82	12.66	29.25
Powerlifting Total (kg)	43.5 ± 20.7	47.3 ± 28.0	0.15	6×	33.21	53.85	29.48	65.07
Wilk's coefficient	27.0 ± 13.0	27.1 ± 14.3	0.01	6×	20.50	33.42	17.98	36.21
Fat-free mass (kg)	1.7 ± 1.0	2.6 ± 2.9	0.42	6×	2.53	4.75	1.56	9.72
Fat mass (kg)	-0.6 ± 2.4	-0.3 ± 4.2	0.09	6×	−1.76	0.62	−2.93	2.43

*ES = effect size; 1RM = 1 repetition maximum.

Procedures

Body Composition. Subjects first visited the laboratory in an overnight fasted state (≥8 hours) for body composition assessment. Before any data collection, subjects were given an informed consent, basic health history form, and a demographics survey asking them to detail their training experience. Once completed, the forms were examined by a research team member to ensure that they were eligible to participate in the study. Subjects were then asked to remove their shirt and shoes to have their height and body mass taken on a calibrated physician beam scale (Health-o-Meter model 420KL; McCook, IL, USA). Body composition was then assessed using a Body-Metrix BX-2000 A-mode ultrasound (IntelaMetrix, Livermore, CA, USA) with a standard 2.5-MHz probe. This device has been reported to be a valid tool for estimating fat-free mass (FFM) in collegiate, resistance-trained athletes when compared with hydrostatic weighing (31) and air displacement plethysmography (17). The ultrasound probe was connected by USB to a standard laptop computer with corresponding proprietary software (BodyView Professional Software; General Electric Company, Milwaukee, WI, USA), which was subsequently used to measure the fat thickness at 7 different sites. All measurements were taken while the participant was in the standing position.

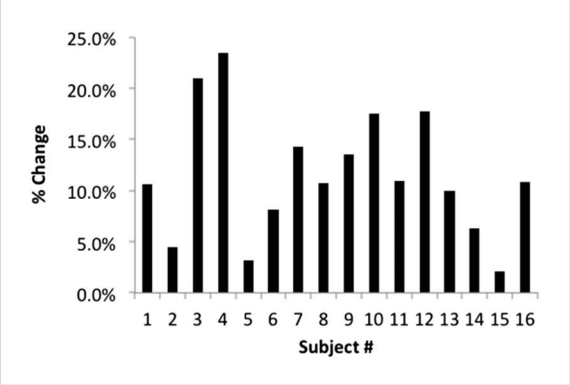

Figure 2. Individual subject plots for 3× per week group in terms of % change in powerlifting total from pretesting to posttesting.

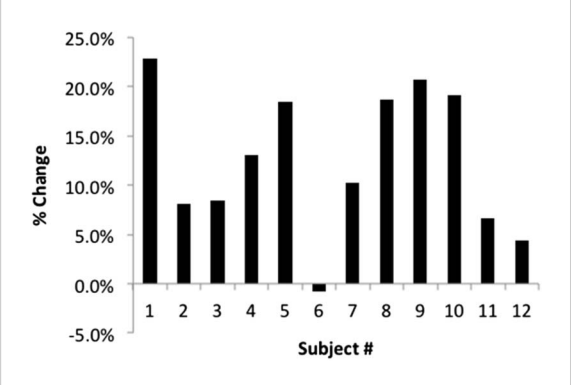

Figure 3. Individual subject plots for 6× per week group in terms of % change in powerlifting total from pretesting to posttesting.

Measurements were taken on the right side of the body using the seven-site skinfold locations in accordance with Jackson et al. (15). The 7 anatomical sites that were measured included the chest, midaxillary, triceps, subscapular, abdomen, suprailiac, and thigh. Measurements were made by applying transmission gel to the probe and lightly placing the probe perpendicular to the site. Each site was measured 2 to 3 times, based on the software's agreement between measurements. The subcutaneous fat thickness was calculated by the device software using an average of the trials. The site-specific subcutaneous fat thickness values were used to calculate body fat percentage using the Jackson Pollock 7-site skinfold equation (15). All body composition assessments were completed by the same technician. The calculated FFM test-retest reliability for the technician that performed all body composition assessments using the same device used in the current study was: intraclass correlation coefficient 0.98; SEM 0.66 kg; and minimal difference 1.83 kg.

Maximal Strength Testing. Maximal strength testing was conducted approximately 24 hours after body composition testing. Subjects were instructed to cease any anabolic dietary supplements (i.e., creatine, beta-hydroxy beta-methylbutyrate) 4 weeks before enrolling in the study. Subjects were, however, allowed to continue whey protein and multivitamin/mineral supplementation throughout the duration of the intervention. Subjects were asked to refrain from any caffeine or supplementation for 12 hours before completing strength testing. Maximal strength was assessed using the National Strength and Conditioning Association's 1RM Testing Protocol (11) for the back squat, bench press, and deadlift. For a lift to be deemed successful, the subject had to complete each lift in accordance with the rules set forth by USA Powerlifting (USAPL). For example, USAPL states that all bench press repetitions must include a pause on the lifter's chest, in which the bar is motionless. The lifter then receives a "press" command, in which they must return the bar upward and extend the elbows in order for the repetition to be deemed successful. On completion of the 1RM testing, the participants' powerlifting total (PLT) was calculated by adding the 1RM of each lift. In addition, WC was calculated by multiplying the PLT by a standardized body mass coefficient.

Resistance Training Protocol. The resistance training sessions were directly supervised by qualified research personnel in the laboratory. The resistance training protocol used a daily undulating periodization scheme and was designed to use a high degree of specificity toward the powerlifts (squat, bench press, and deadlift) while equating volume, intensity, and time spent training between groups. To accomplish this, the 6× per week group completed half as much volume as the 3× per week group in each training session. However, because of the volume-matched resistance training prescription, participants in both groups had the same weekly time commitment (i.e., 6 $h \cdot wk^{-1}$). For example, the 6× per week group's average training session lasted 1 hour, whereas the 3× per group's lasted approximately 2 hours per training session. To prescribe appropriate progression, autoregulated progressive resistance exercise (20) was used to apply the appropriate progressive overload based on the individual subject's performance in the same manner as previous studies in this population (4). Therefore, the volume and intensity completed by each subject varied slightly. Subjects in both groups were also provided approximately 25 grams of whey protein isolate (Dymatize ISO100 Protein) after workout. A sample week of the resistance training protocol for the main dependent variables (DVs) (squat, bench press, and deadlift) is outlined below in Table 1. Subjects also completed training for the rhomboids, latissimus dorsi, deltoids, biceps, triceps, and abdominals throughout the training week.

Statistical Analyses

All statistical analyses were completed using SPSS (version 21; IBM, Armonk, NY, USA). Descriptive statistics (mean ± *SD*) were calculated for each DV at pretesting and posttesting. Independent-samples t-tests were used to determine whether any significant baseline differences existed between groups. Data for each DV were subsequently analyzed using a 2 × 2 between-within factorial analysis of variance. Cohen's d was calculated using difference between the 6× group and the 3× group mean changes divided by the pooled SD of the change scores (6). Effect sizes were interpreted as small ($d = 0.2$), moderate ($d = 0.5$), and large ($d \geq 0.8$) (3). The alpha criterion for significance was set at 0.05 and 95% confidence intervals were calculated for each DV.

Results

For both training groups, a Shapiro-Wilk's test ($p > 0.05$) and a visual inspection of their histograms, normal Q-Q plots, and box plots showed that all maximal strength data variables were normally distributed (30). There was a main effect for time for all strength-related variables ($p < 0.001$). There were no group × time interaction effects observed for squat 1RM ($p = 0.845$), bench press 1RM ($p = 0.843$), deadlift 1RM ($p = 0.611$), PTL ($p = 0.738$), or WC ($p = 0.482$). In addition, there were no significant differences in volume ($p = 0.825$) or intensity ($p = 0.375$) between groups. For body composition, there was a significant main effect for time for FFM ($p < 0.001$) and body mass ($p < 0.001$), but not for fat mass (FM) ($p = 0.520$) or body fat % ($p = 0.118$). There were no group × time interaction effects observed for any body composition variable assessed. The pretesting to post-testing changes for both groups, along with the effect size data and 95% confidence intervals, are outlined in Tables 2 and 3 below. Individual subject plots for improvement in PTL are also presented below in Figures 2 and 3.

Discussion

The primary finding of the present investigation was a significant increase in maximal squat, bench press, and deadlift 1RMs, PLT, WC, and FFM in both the 3× and 6× groups after 6 weeks of supervised resistance training. The findings of this study corroborate our original hypothesis, in which we suspected that both groups would achieve similar strength gains because of the volume- and intensity-matched nature of the training, despite the 6× per week group participating in twice as many training sessions as the 3× per week group. Furthermore, these results indicate that volume seems to be a more important contributor than resistance training frequency to the strength and hypertrophic adaptations observed in response to resistance training, which is in line with previous research (22–27).

It has been suggested that increasing the frequency of resistance training may accelerate neural adaptations and lead to more rapid increases in strength development (12,13). Furthermore, it has been theorized that undertaking resistance training of sufficient intensity on a more frequent basis results in more frequent stimulation of high-threshold motor units (14), which have been shown to be integral in the development of maximal strength (9). Although neural adaptations were not measured in this study, our indirect maximal strength data may suggest that this is not the case in a short-term (6 weeks) resistance training program in trained men. In contrast to our data, however, McLester et al. (21) reported significantly greater increases in both upper- and lower-body maximal strength in subjects who completed a high-frequency (3× per week) compared with a low-frequency (1× per week) resistance training program. Specifically, the authors reported that the low-frequency group achieved 62% of the strength gains observed in the high-frequency group. However, our results showed no significant difference between resistance training frequencies, with a 0.9% difference in percent change of 1RM bench press being the largest difference between groups in strength measures. It is interesting to point out, however, that the effect sizes favored the 6× group for increases in all strength-related variables (with the exception of bench press). This may suggest that high-frequency, lower volume training may produce better improvements in maximal strength over less frequent, higher volume training sessions. However, these data should be interpreted with caution until further investigations can be completed because the effect sizes were trivial or small.

Our data, together with that of McLester et al. (21) may suggest that any effect seen with increasing training frequency may diminish as frequency is increased. For example, there may be benefit in increasing training frequency from once per week to 3 times per week (21), but perhaps no additional effect from increased frequency from 3 times per week to 6 times per week (as our data shows). This apparent decrease in the amount of adaptation observed as frequency is increased, consistent with the law of diminishing returns, has also been observed for resistance training volume (22,24–26). For example, previous work by Robbins et al. (26) reported that although 8 sets of resistance training lead to significantly greater increases in maximal strength than 1 set, there was no statistical difference between a 4-set and an 8-set group. This outcome is also supported by the meta-analysis of Rhea et al. (25), which suggested that training each muscle group 2 times per week with 4 sets per muscle group was optimal for strength gains in previously resistance-trained men. On the surface, a potential benefit of increasing training frequency to such high levels as in this study (i.e., 6 times per week) would be to accumulate additional volume. We volume-matched each group in this study; therefore, the 6× group in our study completed only 2 sets per exercise in each training session. However, this is fairly atypical when designing resistance training programs. By increasing the number of training sessions in a week and maintaining the number of sets per session, the participant can easily accumulate more volume. However, given the

diminishing returns observed with increasing weekly resistance training volume, it is not clear whether increasing resistance training frequency to increase volume would be efficacious for eliciting greater improvements in muscle strength and hypertrophy. Therefore, future research should examine the effects of increased training volume in concert with increases in training frequency.

With respect to skeletal muscle hypertrophy and increases in FFM, previous research has shown muscle protein synthesis to be elevated for 24–36 hours after an acute bout of resistance training. A recent investigation by Damas et al. (5) proposed that elevations in myofibrillar muscle protein synthesis (MyoPS) after resistance training primarily contributes to skeletal muscle repair, as opposed to muscle hypertrophy, until muscle damage is attenuated. Therefore, the authors suggest that "muscle hypertrophy is the result of accumulated intermittent changes in MyoPS after a progressive attenuation of muscle damage (5)." In this study, we observed no significant difference for the increases in FFM observed in response to 3× or 6× training. However, it is interesting to note that the effect size for the increase in FFM ($d = 0.42$) favored the 6× group, with neither group reporting significant changes in body fat percentage or FM. Thus, it is possible that the 6× group experienced more frequent acute elevations in MyoPS because of the increased frequency of training. These results partially support the work of Schoenfeld et al. (29), in which they showed significantly greater increases in muscle thickness of the elbow flexors in a whole body (3× per week frequency), when compared with a split resistance training program (1× per week frequency). In conjunction with the present findings, it seems that more frequent training may provide the most favorable conditions to elicit muscle hypertrophy. However, these data should be interpreted with caution because we did not have any direct measure of hypertrophy, nor did we control for nutritional intake throughout the study duration.

Although high-frequency training does not seem to offer any additional benefits beyond that of lower frequency, volume-equated training, coaches and athletes may be presented with scenarios that necessitate increased training frequency. Some of these scenarios may include a daily training volume that is no longer manageable for athletes, time constraints in an athlete's schedule, and/or overall personal preference. These scenarios may warrant increased resistance training frequency and coaches use an increased training frequency to accommodate the schedule and preferences of athletes when other program variables (i.e., volume and intensity) are held constant with equivocal results. However, the effects of increased training frequency with a simultaneous increase in training volume and intensity are presently unknown and need to be investigated.

Practical Applications

Based on this study and previous investigations, it seems that volume and intensity should be the primary concern of coaches and practitioners when designing a periodized resistance training program. Our data suggest that athletes will receive no further benefits from increasing training frequency without a subsequent increase in training volume and/or intensity. It is the opinion of the authors that coaches should increase training frequency when necessitated by an increase in training volume and intensity beyond the athlete's current recovery capabilities. However, further research is needed to validate this hypothesis. Previous investigations have suggested that 3 weekly training sessions produces more optimal adaptations than 1 or 2 weekly strength training sessions. The results of this study suggest, however, that frequency seems to follow the law of diminishing returns because 6 weekly training sessions does not seem to offer any additional benefits beyond 3 weekly sessions when training volume and intensity are equated. Athletes and coaches may be presented with scenarios that may necessitate increased frequency, including a daily training volume that is no longer manageable for athletes, time constraints in an athlete's schedule, and/or overall personal preference. These scenarios may warrant increased resistance training frequency and coaches may choose to use an increased training frequency to accommodate the schedule and preferences of athletes without a decrease in training adaptations when other program variables (i.e., volume and intensity) are held constant. However, the effects of increased training frequency with a simultaneous increase in training volume and intensity are presently unknown and warrant further investigation.

Acknowledgments

The authors thank Dymatize Athletic Nutrition Institute for their protein donation to the study. The authors have no conflicts of interest to disclose.

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