Strength Gains after Resistance Training: The Effect of Stressful, Negative Life Events

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Abstract

Bartholomew, JB, Stults-Kolehmainen, MA, Elrod, CC, and Todd, JS. Strength gains after resistance training: the effect of stressful, negative life events. *J Strength Cond Res* 22: 1215–1221, 2008—This study was designed to examine the effect of self-reported, stressful life events on strength gains after 12 weeks of resistance training. Participants were 135 undergraduates enrolled in weight training classes that met for 1.5 hours, two times per week. After a 2-week period to become familiar with weight training, participants completed the college version of the Adolescent Perceived Events Scale (APES), the Social Support Inventory, and one-repetition maximal lifts (1RM) for the bench press and squat. Maximal lifts were repeated after 12 weeks of training. Median splits for stress and social support were used to form groups. Results indicated that the low stress participants experienced a significantly greater increase in bench press and squat than their high stress counterparts. Strength gains were, however, unrelated to social support scores in either the low or high stress group. High life stress may lessen a person's ability to adapt to weight training. It may benefit coaches to monitor their athletes' stress both within and outside the training setting to maximize their recovery and adaptation.

Key Words one-repetition max, muscular hypertrophy, social support

Introduction

Rarely do two athletes respond the same to training. Regardless of similarities in body composition, diet, work ethic, or age, some athletes invariably adapt better to training than others. Although there are unobservable differences between these individuals (e.g., at the cellular and molecular level), variations in training response may also follow differences in their experience of life stress. Life stress has been conceptualized as the culmination of major change events (such as a marriage, divorce, or loss of employment) that result in a cascade of physiological events that begin with an increased activation of the sympathetic/adrenal-medullary (SAM) system and hypothalamic-pituitary-adrenal (HPA) axis (41). Unfortunately, stressful life events are often associated with a lasting stress response that lacks the opportunity for recovery, thus taking its toll on the human organism (14,35). It has been well documented that a disproportionate exposure to life stress has negative implications for people's health (10), including the number of illnesses they experience as well as rates of morbidity (16).

Although generally placed in a negative light, the stress response can be facilitative when paired with adequate recovery. Selye theorized that under these conditions, the stress response provides the means for adaptation by developing stress resistance and improving capacity (38). Indeed, the specific goal of periodized exercise training is to balance stress and recovery as a means to improve strength and fitness. Given this perspective, is it reasonable to ask how stressful life events affect this balance of stress and recovery? That is, life stress may undermine recovery and adaptation. Potential mechanisms include decreased training effort in response to stress or differences in biological responses (34). Regardless of the mechanism, it is sensible to investigate the impact of stress on the response to strength training. This new line of inquiry represents a shift in focus from the study of illness as the primary outcome of stress and stress-related disorders to an emphasis on the potential impairment of fitness-related constructs.

The effect of stress on health, however, is not invariant and is moderated by a number of variables (8). For example, social support, defined as the presence of people who we believe value us and on whom we can rely, has consistently been shown to reduce the health-related impact of stress (36,37). As a result, if stressful life events do lessen the response to exercise training, social support may moderate this relationship. This would be manifest through an interaction between stress and social support, in which the training response would be least for those who reported both a disproportionate number of stressful life events and low social support. The present study was designed to investigate this issue. Life stress was operationally defined as the summed total of

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negative life events (each rated by their impact and desirability) over the previous 3 months. Strength was defined as the change from pre- to posttesting in one repetition maximum lifts (1-RM) for the bench press and squat. Changes in muscle mass were defined as area-specific (upper arm and thigh) measures of circumference less skinfold. Training was based on 12 weeks of supervised resistance exercise workouts two times per week.

There are a number of reasons to expect high life stress to lessen the training effect of exercise (e.g., increased basal cortisol [30], poor recovery, changes in nutrition [3], illness and related absence from training [43]). However, an assessment of potential mediators is beyond the scope of this investigation. We were interested in determining the extent to which life stress might impact the training response to resistance exercise.

Methods

Experimental Approach to the Problem

To investigate the impact of stress on muscular strength and hypertrophy development, we evaluated these adaptations within a prescribed weight training regimen in a college instructional setting. Measures of stress and social support measured at the beginning of the training session were hypothesized to moderate the normal adaptation to this training with those in the high stress category and with low social support hypothesized to have the smallest gains in strength and hypertrophy as measured by changes from pre- to posttraining. Those with low stress and high social support, conversely, may have the greatest gains in hypertrophy and strength.

Subjects

The sample for this study comprised 173 college-aged students recruited from a weight training class at a large metropolitan university in the southwestern United States. Of the participants initially recruited, 135 participants completed all of the requirements of the study. The final sample was composed of 81 men and 54 women with varying degrees of training experience, from the beginner to the advanced levels. These classes are designed for non-kinesiology majors and therefore represent a population that has little specific training in exercise-related topics. This study was approved by the university's institutional review board for human subjects research, and a signed, informed consent was gathered from each participant before any testing.

Exercise Training

Each participant underwent a 2-week familiarity program and a 12-week periodization-training program involving resistance training of all major muscle groups of the upper and lower body (23). Training was supervised 2 days a week, for 1 to 1.5 hours per day. The familiarity program involved instruction in the performance of all lifts. Upper-body lifts performed were the bench press, incline press, overhead press, biceps curls, triceps extensions, dumbell rows, and lat pull-downs. Lower-body lifts performed were the squat and the leg press. High pulls were performed as a whole-body exercise. Participants performed both upper-body and lower-body lifts on every training day. The training program involved three mesocycles, each lasting approximately 4 weeks. In the hypertrophy cycle, after one or more warm-up sets, participants lifted three sets of 10 repetitions on each exercise. Rest periods were 1–2 minutes in duration. During the basic strength cycle, participants warmed up, then performed three sets of five repetitions on each exercise. Finally, during the power cycle, participants warmed up and lifted three sets of three repetitions on each exercise. Rest periods were 3–5 minutes in length during the strength and power phases. The 1RM target method was utilized to increase training load each week. More specifically, within each cycle, the weight lifted was continually adjusted to match increasing strength according to the appropriate RM target (i.e., 10RM, 5RM, or 3RM).

Class instructors monitored progression daily to make sure that students were following the hypertrophy, strength, and power prescriptions. Participants completed daily workout logs that were checked twice a semester. Each individual was encouraged to complete a third session of exercise each week on their own initiative, but these efforts were not assessed. No other changes were made to subjects' normal patterns of work and recreational physical activities.

Physical Measures

All physical testing occurred after the 2-week familiarization period. Each participant performed a 1RM lift on the bench press and the squat. Before testing, each participant warmed up by performing five to eight repetitions using a light weight. A 1RM lift was then performed. If the weight was lifted successfully, the participant was allowed to recover, more weight was added, and the lift was attempted again. This process continued until the participant failed on a lift or volitionally decided that he or she could not lift any more weight. Although weights were self-selected, an investigator supervised all lifting. A separate pilot study found that the test-retest reliability (Cronbach's α) was 0.987 for the bench press and 0.962 for the squat.

To assess area-specific muscle mass, the circumference of the thigh and upper arm were measured, along with a caliper skinfold measure. Circumferences of the upper arm and thigh were taken at the maximal girth of both areas. Skinfolds of the upper arm were measured at the midline of the posterior aspect of the arm, over the triceps muscle, at a point midway between the acromion process and the olecranon process. Skinfold measurements of the thigh were taken at the midline of the anterior aspect of the thigh, midway between the inguinal crease and the proximal border of the patella. Arm size was calculated by subtracting the caliper pinch taken from the triceps skinfold site from the upper arm circumference measured at the maximal girth of the upper arm. Likewise, thigh size was calculated by subtracting the caliper pinch taken from the thigh skinfold area measured at the maximal girth of the thigh. To maintain consistent measures, the same investigator completed both pre- and post-skinfold measures. Maximal lifts and arm and thigh measurements were reassessed after 12 weeks of resistance training.

Psychological Measures

Each participant completed two questionnaires that measured level of life events and perceived social support. Life events were measured by the Adolescent Perceived Events Scale (APES) (9), a 207-item questionnaire that evaluates the level of both positive and negative life events experienced by each participant. This instrument asks respondents about major life events (e.g., death of a relative, parents' divorce), daily stressors (e.g., waiting in lines), and pleasures (e.g., listening to music).

For each event, participants indicated whether the item listed had happened to them in the last 3 months. The APES does not rank events for the respondent, as does the Social Readjustment Rating Scale (SRRS) (14). Nevertheless, life events vary in their valence and significance; therefore, assessment of each life event is desirable. Consequently, respondents self-rated each event with impact and desirability scores. Desirability was rated on a scale from −4 to +4 with −4 being "extremely undesirable" and +4 being "extremely desirable," whereas impact was rated on a scale from 1 to 9 with 1 having "no impact" and 9 having "extreme impact." Each item was weighted by the desirability rating multiplied by the impact rating. As an example, an athlete may rate a divorce that happened within the last 3 months as having a desirability of −4 with an impact of 8, resulting in a score of −32 for that event. This protocol allows for superior assessment of stress as it allows for an individualized rating of each event. This scale demonstrates high levels of reliability and validity for adults of college age (9,40). Because negative events have shown a stronger relationship with athletic outcomes, only the negative life scores were utilized in this study (40). Perceived social support was calculated by the Social Support Inventory (SSI) (6). Participants rated how satisfied they were with the different types of help or social support available to them for 39 items, scored on a 7-point Likert-type scale, with 1 being "not at all satisfied" and 7 being "very satisfied." The ratings were then totaled to calculate the participant's social support score.

Statistical Analyses

To meaningfully interpret increases in strength for both genders, bench press and squat scores were expressed as a function of kilograms of body weight. Median splits were applied to social support and negative life stress event scores to divide participants into high and low social support and high and low stress groups. This was done to facilitate the planned analysis of variance (ANOVA). To determine whether the training protocol was sufficient to produce changes in strength and hypertrophy, separate one-way, repeated-measures ANOVAs were completed for the pre versus post measures. To examine the effect of stress and social support on the change in strength, separate 2 (stress) × 2 (social support) × 2 (time) ANOVAs with repeated measures on the last factor were completed for both the bench press and the squat data. The α level for significance of the analyses was set to $p \leq 0.05$ and the n-size was 135.

Results

Performance data for all groups are presented in Table 1. The one-way ANOVAs assessing changes in strength and hypertrophy pre versus post determined that there was a significant main effect change in bench press over time ($F[1, 130] = 326.53$, $p < 0.05$), which represented an average 13% increase over the 12 weeks. Likewise, there was a significant main effect change in squat over time ($F[1, 130] = 544.86$, $p < 0.05$), which represented an average 25% increase over 12 weeks. There was a significant change in arm size over time ($F[1, 130] = 109.17$, $p < 0.05$), which represented an average 18% increase over 12 weeks, but the change in thigh size was not significant ($p > 0.10$). There were no differences between the two stress groups in terms of baseline physiological measures (e.g., bench and leg press, muscle mass of the upper arm and thigh) ($p > 0.10$).

Table 1. Pre and post data for bench press, squat, arm, and thigh size.

	Bench 1	Bench 2	%Change
Low stress	129.73 (55.88)	148.67 (60.34)	14.60
High stress	127.16 (62.57)	142.02 (67.57)	11.68
	Squat 1	Squat 2	
Low stress	177.66 (67.70)	222.19 (71.98)	25.06
High stress	173.88 (86.54)	212.84 (93.58)	22.41
	Arm size 1	Arm size 2	
Low stress	15.04 (7.25)	18.00 (6.97)	19.68
High stress	14.36 (6.75)	16.82 (6.78)	17.13
	Thigh size 1	Thigh size 2	
Low stress	33.70 (7.83)	34.16 (8.93)	1.36
High stress	32.45 (8.85)	32.50 (9.27)	0.15

Values are means (standard deviation).

The repeated-measures ANOVAs revealed that the predicted three-way interaction was not significant, but there was a significant stress × time interaction for bench press ($F [1, 127] = 5.11, p < 0.05$). The simple effects of time within each level of stress revealed a significant increase in performance for both groups: the low stress group ($F [1, 129] = 202.16$, $p < 0.05$) represented an average increase of 15%, and the high stress group ($F [1, 129] = 127.80, p < 0.05$) had an average increase of 12%. Thus, although both groups responded with significant increases in bench press, the low stress group responded with greater improvement. There were no significant main effects for social support on bench press ($p > 0.10$), and social support did not interact with other variables ($p > 0.10$).

With regard to squat, the predicted three-way interaction was not significant, but there was a significant stress × time interaction ($F [1, 127] = 3.92, p = 0.05$). The simple effects of time within each level of stress revealed a significant increase in performance for both the low stress ($F [1, 129] = 394.30$, $p < 0.05$, an average 27% increase) and the high stress groups ($F [1, 129] = 304.80$, $p < 0.05$, an average 23% increase). Thus, although both groups responded with significant increases in bench press, the low stress group responded with greater improvement. There were no significant main effects for social support on squat, and social support did not interact with other variables. Neither arm nor thigh size was affected by stress or social support, with all p values >0.15. Men accounted for 67% of the low stress group and 55% of the high stress group, but analyses revealed that no differences in bench or leg press strength between stress groups could be explained by gender (all p values >0.10).

Discussion

This study was designed to examine the effect of life stress on strength after a period of resistance exercise training. The resistance training followed a high-quality periodization schedule and resulted in an average increase of 13% for the 1RM bench press and 25% for the 1RM squat. As predicted, results indicated that those individuals who reported high negative life-event stress experienced less improvement in strength compared with those who reported low negative life-event stress. Thus, resistance exercise training did not neutralize or buffer the physiological effects of life stress–rather, stressful life events seem to compromise a person's ability to fully adapt to training. These effects, although significant, were relatively small to moderate in magnitude.

There are several potential physiological mechanisms that might explain this finding. Life stress may interfere with the strength adaptation process in several systems, including the sympathetic adrenal-medullary (SAM), neuroendocrine (HPA axis), and immune systems (7,31,33). Stress is related to increases in epinephrine, lower peak levels of beta-endorphin and natural killer (NK) cell lysis, and more pronounced redistribution of NK cells (39). Chronic stress also interferes with neurogenesis (42). Finally, cortisol, a primary stress-response hormone produced through the HPA axis, is also increased with both physical and mental stress. This adrenocortical steroid hormone controls muscle protein turnover and can act directly at the level of the gene within muscle cells, altering transcription and subsequent translation of specific proteins (12,25). As a result, tissue and muscle wasting (catabolism) occurs with prolonged high concentrations of cortisol in the blood (20), which may interfere with recovery. A recent prospective study conducted by Ebrecht and colleagues (11) studied the effects of perceived stress on cortisol production and on the speed of healing from a puncture wound to the skin. A median split of the complete sample found that slow-healing participants reported higher stress and cortisol levels compared with the fast-healing participants. Perna and McDownell (30) studied a group of very fit runners and found that the cortisol response in the 2 days preceding a maximal treadmill test was exaggerated among those who reported high levels of life-event stress. Future studies should examine the impact of neuroendocrine hormones on the life stress and strength adaptation relationship.

Although stress may impair adaptations to exercise (improved fitness), exercise may, in turn, obviate the effects of stress. Unfortunately, this study was not designed to address the issue of the stress-coping benefits of exercise. Resistance exercise has been shown to reduce the experience of stress. For example, Horowitz et al. (15) reported that participants who participated in a 10-week circuit-training program demonstrated significant reductions in school, personal, relationship, and total stress. The effects of resistance training on cortisol production are equivocal, with some studies finding decreases in cortisol production with training (26), others finding increases in cortisol with training (21), and others finding mixed results depending on the population or type of training (1,22). Consequently, although disproportionately high life stress may have a significant impact on one's response to resistance training, exercise may also lessen the impact of stressful events. Thus, although the observed effects in the current study were relatively moderate, they are nonetheless impressive. However, we are aware of no adequate experimental design that would allow for an independent assessment of these effects.

Stress results in numerous behavioral changes (3). It may be that highly stressed participants refrained from exercise outside class or did not willingly exercise at the same intensity as low stress participants. The use of training logs, especially for training outside class, would be helpful in future studies to determine whether groups differ in total training volume. Furthermore, those in the higher stress group may also engage in higher risk behavior as a coping mechanism for stress. Stress has been correlated with poor nutritional habits, decreases in the quantity and quality of sleep, smoking, and alcohol use, all of which can affect adaptation to resistance training (3).

Levels of social support did not moderate these relationships. Social support has been shown to be a significant moderator in other stress-health relationships (37,40) and in the stress-injury relationship (2). Interestingly, the selected method of stress assessment may have obscured any potentially moderating effect of social support. Previous work has utilized scales based on normative ratings to calculate the impact of stressful events. We chose a scale that measured individual ratings of desirability and impact. It may be that the social support has its primary influence on the perceived impact of an event. As a result, social support would not be expected to have a subsequent role in the present study. Future studies may wish to compare different stress assessments to determine the role of social support and the impact of social support on the weighting of negative events. It was also surprising that there were no group differences in hypertrophy. Although a significant increase in arm hypertrophy was found for all participants, it may be that the measure of hypertrophy (circumference minus skinfold) was not sensitive enough to detect differences between conditions. Future studies might wish to use a more sensitive assessment of muscle hypertrophy.

Because the effects of stress were assessed through a median split of the stress scores, it is not clear whether there is a criterion or threshold of stress where one might expect a decline or stunting of the training response. In fact, it is likely that athletes have quite different levels of stress that will elicit disruptions in training. For some, it might be as commonplace as an argument with friends, whereas for others it would require something of much greater magnitude (e.g., a death in the family). Different domains of stress may also have different stress thresholds before they intrude on desired physical outcomes (financial stressors versus interpersonal stressors). In addition, as stress may result in variance of behavior (less intense or less frequent training), outside monitors, such as strength coaches, may lessen these effects because they provide a resource that helps to sustain exercise behavior even in light of increasing life difficulties. Regardless, anecdotal data and case studies have demonstrated that athletes with nearly identical training regimens and similar levels of support from coaches often have differential outcomes that may be related to life-event stress (28).

There are a number of limitations to this study. Specifically, we failed to assess motivation for and attitudes toward training, personality (e.g., trait optimism), and exercise outside class. Each of these might interact with stress to affect the training response; consequently, future studies would benefit from the addition of these variables. Illness is another important consideration, as previous studies have demonstrated a strong link between stress and illness in the training setting. Indeed, one study found that 22–30% of the variance in injuries was explained by life stress as measured by the APES stress inventory (40). Fidelity to the training program and training progression was also not as carefully scrutinized as one might expect in a high-level athletic setting in which each repetition and set may be monitored. An additional limitation is that stress was not measured pre versus post. Certainly, life events occurring during the training program could greatly affect training adaptations. Nevertheless, studies that have utilized the APES stress measure to gauge the effect of stress on injury and illness have only evaluated stress at the beginning of an athletic training period (40,43). Future analyses should also examine differences in the strength-stress relationship by initial training status (experienced versus novice weight trainer) and dropout status. (40,43).

To our knowledge, this is the first investigation to assess the impact of stress on the ability to develop strength through resistance training. Results indicate that although significant increases were seen in both groups, high life stress significantly compromised individuals' ability to develop strength. This study lends credence to various theories advanced in recent years concerning the relationship among training, stress, recovery, adaptation, and performance, such as the Biopsychological Stress Model (17,24) and the Multi-Systemic Model of Stress (28). Furthermore, this investigation may be directly applied to the study of overtraining syndrome (13,27,28), which seems to be the result of a disruption of the tailored balance of stress and recovery. Therefore, further research should include a group of athletes, as this population of individuals has a unique set of stressors (29).

Practical Applications

Previous research demonstrates that exercise may allay the effects of stress and may help individuals to manage stress within their lives (4,5,32). Nevertheless, the current study suggests that experience of stress may impair one's ability to fully adapt to training. Those participants who experienced a greater quantity of stressful life events improved to a lesser degree than those low in life-event stress. It is not certain how stress may impair the adaptation process. It may undermine one's training through diminished exercise behavior or perceptions regarding one's training load and progression, or it may impair the recovery process, either by affecting behaviors that may promote recovery (nutrition, sleep, etc.) or underlying biological factors responsible for anabolism/catabolism or immune functioning and illness. Regardless of the cause, the ubiquitous nature of stress suggests clear implications for strength coaches. For example, it is common for coaches to observe athletes of similar physical aptitude and work ethic responding differently to prescribed training regimens (28). Where inordinate life stress contributes to differential responses, it is likely that these results will be met with great frustration as individuals reach an early plateau and fail to achieve their potential. It may benefit coaches to monitor their athletes' stress both within and outside the training setting to maximize their adaptation and to maintain perseverance despite poor results. Practical, cost-effective systems for monitoring stress and recovery among athletic populations have been published in the strength literature (18,19). We suggest that utilizing these systems will assist practitioners in identifying early signs of inadequate recovery.

Following these or similar procedures might be a useful means to incorporate the results of this study into applied training sessions.

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