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Research article

SALIVARY CORTISOL RESPONSES AND PERCEIVED EXERTION DURING HIGH INTENSITY AND LOW INTENSITY BOUTS OF RESISTANCE EXERCISE

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ABSTRACT

The purpose of this study was to measure the salivary cortisol response to different intensities of resistance exercise. In addition, we wanted to determine the reliability of the session rating of perceived exertion (RPE) scale to monitor resistance exercise intensity. Subjects (8 men, 9 women) completed 2 trials of acute resistance training bouts in a counterbalanced design. The high intensity resistance exercise protocol consisted of six, ten-repetition sets using 75% of one repetition maximum (RM) on a Smith machine squat and bench press exercise (12 sets total). The low intensity resistance exercise protocol consisted of three, ten-repetition sets at 30% of 1RM of the same exercises as the high intensity protocol. Both exercise bouts were performed with 2 minutes of rest between each exercise and sessions were repeated to test reliability of the measures. The order of the exercise bouts was randomized with least 72 hours between each session. Saliva samples were obtained immediately before, immediately after and 30 mins following each resistance exercise bout. RPE measures were obtained using Borg's CR-10 scale following each set. Also, the session RPE for the entire exercise session was obtained 30 minutes following completion of the session. There was a significant 97% increase in the level of salivary cortisol immediately following the high intensity exercise session ($p<0.05$). There was also a significant difference in salivary cortisol of 145% between the low intensity and high intensity exercise session immediately post-exercise ($p<0.05$). The low intensity exercise did not result in any significant changes in cortisol levels. There was also a significant difference between the session RPE values for the different intensity levels (high intensity 7.1 vs. low intensity 1.9) ($p<0.05$). The intraclass correlation coefficient for the session RPE measure was 0.95. It was concluded that the session RPE method is a valid and reliable method of quantifying resistance exercise and that salivary cortisol responds promptly to the exercise load.

KEY WORDS: Weight lifting, stress, endocrine effects.

INTRODUCTION

In many studies the endocrine response of subjects to varying types of stress has been tested. Cortisol, the principal glucocorticoid in humans, plays a major role in metabolism and immune function. It has been shown that acute exercise induces a change in plasma cortisol concentrations, which is dependent on the type of exercise (Lac and Berton, 2000; Jacks et al., 2002). Several studies have investigated the effect of both acute and chronic resistance exercise on adrenocortical function (Mulligan et al., 1996; McCall et al., 1999; Fry et al., 2000; Nindl et al., 2001; Smilios et al., 2003). However, there appear to be no studies that have measured salivary cortisol responses to different intensities of resistance exercise.

Salivary measures of cortisol have been shown to be a valid and reliable reflection of serum cortisol (Obminski and Stupnicki, 1997). Salivary cortisol may actually provide a better measure than serum cortisol of the stress response as it more accurately measures the amount of unbound cortisol compared to serum measures (Vining et al., 1983). There is also evidence that suggests fitter individuals show increased cortisol responses compared to less trained individuals (Marthur et al., 1986; Luger et al., 1987).

The Borg 15-category scale for the rating of perceived exertion (RPE) during physical activity has been widely researched for its use in both clinical and exercise settings (Noble and Robertson, 1996). Borg based the RPE scale on the idea that a measure of perceived exertion is the level of strain and/or heaviness experienced during physical effort, as estimated by a specific rating method (Borg, 1998). Since the unveiling of the original scale over forty years ago, the CR-10 RPE scale has become a standard method to evaluate perceived exertion in exercise testing, training, and rehabilitation and has been validated against objective markers of exercise intensity (Borg et al., 1985, Noble et al., 1983). However, to date this scale has not been evaluated to the same extent for other high intensity exercises such as resistance training. A recent study by Gearhart et al. (2001) showed that the Borg CR-10 RPE scale can be used effectively during single set resistance training sessions and that it is a valid measure of exercise intensity. A second study by Gearhart et al. (2002) yielded similar results thus expressing promise to its application of the rating of single set perceived exertion.

A series of studies by Foster (1998), Foster et al. (1996; 2001) and Day et al. (in press) have suggested that a single session RPE rating may accurately reflect the intensity of an exercise session. A recent study conducted by Day et al. (in press) demonstrated that the session RPE could be used to quantify the intensity of a resistance training session. However, the exercise protocol used by Day et al (in press) used a single set format. In addition, the research done thus far using RPE during resistance exercise has not adequately addressed the efficacy of its use during typical multi-set, higher intensity weight training sessions undertaken by many trainees, particularly athletes (Gearhart et al., 2001). It has been suggested that combined psychological and physiological changes during high intensity training provide important indicators for monitoring training stress (Filaire et al., 2001).

Several studies have evaluated training load and prescribing exercise periodization using session RPE (Foster et al., 1996; 2001). Foster et al. (1996) reported that self-directed increases in training load, using the session RPE scale as a marker of intensity multiplied by exercise duration in minutes to yield an index of the total training load, improved athletic performance during cycling time trials. However, another study by Foster et al. (1998) revealed that a sudden increase in training load above normal training limits caused a decrease in endurance performance and led to injury or illness. Periodization or variation of training intensity should be utilized within a weekly training plan and can be monitored using session RPE values obtained by the individual after each exercise session. Session RPE could also lead to optimal athletic performance with a reduced injury/illness cost due to overtraining with endurance exercise.

The purpose of this study was to measure the salivary cortisol responses to different intensities of resistance exercise. The secondary purpose was to evaluate the effectiveness of using the session RPE scale to measure physical effort during bouts of resistance training exercise, as well as to examine the validity of this scale in rating entire resistance training sessions of different intensities.

METHODS

Experimental design and approach to the problem

This study used a randomized, crossover design, in which subjects completed two experimental trials twice. For this study, subjects performed a low intensity protocol, and a high intensity protocol for two exercises (the bench press and the squat, respectively). For the purpose of safety and the elimination of possible external variables, which potentially could have affected results, both of these exercises were performed on the Smith Machine. Each subject completed a total of five sessions, on nonconsecutive days. Day one consisted of a familiarization session that included informed consent procedures, instruction on the use of CR-10 RPE scale and session RPE to rate perceived exertion. The subsequent four sessions consisted of two high intensity workouts at 75% of 1-RM and two low intensity workouts at 30% of 1-RM. The order of these sessions was randomized with least 72 hours between each session. The purpose of conducting the resistance exercise sessions on two occasions was to determine the reliability of the session RPE method for rating the intensity of the workout.

Subjects

Seventeen volunteers between the ages of 18 and 25 were recruited for this study including 8 men (Mean ± SD; 21.6 ± 1.2 years; 1.8 ± 0.1m; 86.6 ± 11.0 kg; 11.0 ± 5.2% body fat) and 9 women (20.0 ± 0.9 years; 1.6 ± 0.1m; 60.6 ± 8 kg; 21.2 ± 2.8% body fat). These volunteers were required to meet the following requirements prior to participation in this study: absence of any skeletal, muscle, cardiovascular, or endocrine limitations; a history of a resistance-training program of at least two sessions per week for at least three weeks prior to participation in this study; and free of controlled and performance-enhancing drugs for at least one month prior to and for the duration of the study. Subjects provided informed consent as per the university's Institutional Review Board. All subjects were measured for height, body mass, and percent body composition during the first testing session. During the duration of the study subjects were required to refrain from intense exercise 24 hours prior to each testing session, to follow the same diet on each day of each trial, and not to eat for at least 3-4 hours prior to any testing session. In addition, subjects were instructed to abstain from alcohol and caffeine for a minimum of 24 hours prior to any testing session. Percent body fat was estimated using four site measurements of skinfolds as per Durnin and Wormesley (1973)

Strength testing

At least one week prior to the acute resistance exercise protocol, each subject had their one repetition maximum (1RM) determined on the Smith machine squat and Smith machine bench press as previously described (Kraemer et al., 1998). This involved a number of warm-up trials being performed using 30% (8-10 reps), 50% (4-6), 70% (2-4), and 90% (1 repetition) of an estimated RM or 1-1.5 times subjects body weight (McBride et al., 2002). Following the warm-up the subjects' resistance was increased where the individual completed a number of maximal efforts to determine 1RM.

Acute resistance exercise protocol

The high intensity resistance exercise protocol consisted of 6 sets of 10 RM squats (75% of 1RM) and 6 sets of 10RM bench presses (75% of 1RM) with 2 minutes of rest between each set. A similar protocol has been previously used and has shown to result in changes in endocrine function (Hymer et al., 2001). If the subject failed to perform the 10 repetitions on any given set due to fatigue the load was immediately adjusted to permit completion of the remaining repetitions. The low intensity resistance exercise protocol consisted of 3 sets of 10 repetitions at 30% of 1RM of the same exercises as the high intensity protocol with 2 minutes of rest between each exercise.

Rating of perceived exertion measures

During the familiarization session, each subject was given instructions on the use of the modified CR-10 category RPE scale (Noble et al., 1983; Borg et al., 1985). The session RPE measure, which was developed by Foster et al. (1996; 2001), was used to rate intensity of the entire workout (Figure 1). A series of anchoring tests was used as previously described by Gearhart et al. (2001) to establish high and low perceptual anchors. In addition, the subject was shown the scale 30 minutes following conclusion of the training bout and asked, "How was your workout?" (Foster et al., 2001). RPE was taken 30 minutes post-exercise to prevent particularly difficult or easy elements near the end of the exercise session from skewing the overall rating of the session. As a comparison to studies where duration was multiplied by the session RPE to calculate the training load, we multiplied the session RPE by the number of sets performed, the number of repetitions performed and weight lifted to create a term representative of the training load. The goal of the session RPE is to encourage the subject to view the training session globally and to simplify the myriad of exercise intensity cues during the exercise bout.

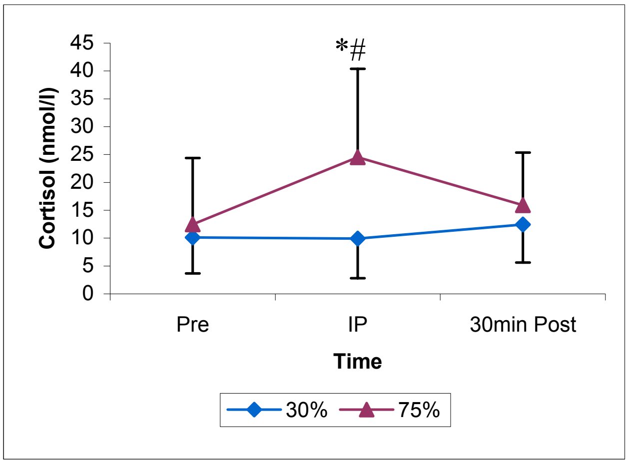

Figure 1. Mean salivary cortisol concentrations (±SD) before exercise, immediately following exercise and at 30 minutes of recovery (n = 10).
* denotes significant differences between exercise time points. # denotes significant differences between the low intensity and high intensity exercise sessions.

Salivary cortisol

Saliva samples were collected at the beginning of each testing session (without stimulation, by spitting directly into a plastic tube), immediately following completion of the resistance exercise session and 30 minutes following completion of the last exercise (at the same time as the obtaining the session RPE). Samples were obtained for all the testing sessions from ten of the subjects who completed the study. Salivary cortisol has been shown to have a circadian rhythm (Thuma et al., 1995; Raff et al.1998). To avoid any confounding effects due to variations in circadian rhythm all testing sessions were performed at the same time of day. Samples were stored at -80ºC until analyzed. There is a strong relationship between salivary and serum unbound cortisol both at rest (r = .93) and during exercise (r = .90) (O'Connor and Corrigan, 1987). Saliva measures of cortisol concentrations are independent of saliva flow rate (Riad-Fahmy et al., 1983). Salivary cortisol concentrations were determined in duplicate by Enzyme Immunoassay using a Diagnostic Systems Laboratories Salivary Cortisol Enzyme Immunoassay Kit (DSL, Webster, Texas). Assay plates were read using an *Opsys* MR^{TM} Microplate Reader (Dynex Technologies, Chantilly, USA). Intra-assay variance was 7.2% and the sensitivity of the assay was 0.011 $\mu g \cdot dL^{-1}$.

Statistical Analysis

Statistical significance was set at the $p < 0.05$ level. Changes within groups for salivary cortisol measures and RPE values were analyzed using two way repeated measures analysis of variance. Comparisons among the groups were made using analysis of variance. The Tukey post-hoc test was used to identify significantly different group means. Each subject's RPE values was averaged and compared to his/her session RPE rating. This test was completed to identify if significant differences exist between the session RPE rating and the accumulated RPE ratings obtained during each resistance training session. Interclass correlation coefficients (ICC) were calculated to establish the reliability of the session RPE method. Bivariate relationships were calculated using Pearson's product moment correlations to examine the relationship between changes in cortisol levels and session RPE. Lastly bivariate correlations were computed relating changes in cortisol and training load.


Rating = Descriptor
0 = Rest
1 = Very, Very Easy
2 = Easy
3 = Moderate
4 = Somewhat Hard
5 = Hard
6 = *
7 = Very Hard
8 = *
9 = *
10 = Maximal

Figure 2. Modification of the category ratio rating of perceived exertion (RPE) scale for this study (Foster, 2001). The verbal anchors have been changed slightly to reflect American English (eg. light becomes easy; strong or severe becomes hard). Briefly, the subject is shown the scale approximately 30 minutes following the conclusion of the training bout and asked "How was your workout?".

RESULTS

There was a significant increase in the level of salivary cortisol immediately following the high intensity exercise session (Figure 2). There was a significant difference between the low intensity and high intensity exercise session immediately post-exercise. The low intensity exercise did not result in any significant changes in cortisol levels.

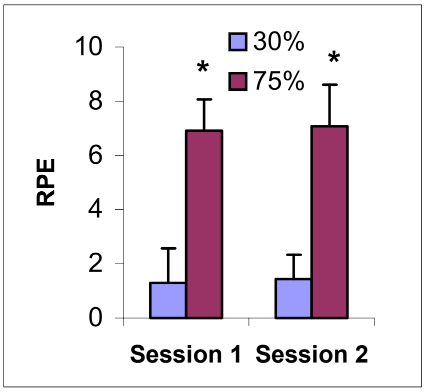

Figure 3. Average RPE for the bench press exercise during each testing session. * denotes significant differences between 30% and 75% exercise bouts.

There was a significant difference between the mean RPE values for each intensity ($p < 0.05$) (Figure 3 and 4). There was also a significant difference between the session RPE values for each intensity of lifting (high intensity 7.1 vs. low intensity 1.9) ($p < 0.05$) (Figure 5). There was no significant difference between the average RPE values and the session RPE values for the squat exercise. However, there was a significant difference between the average RPE value for the bench press exercise and the session RPE value during each intensity for the bench press exercise ($p < 0.05$).

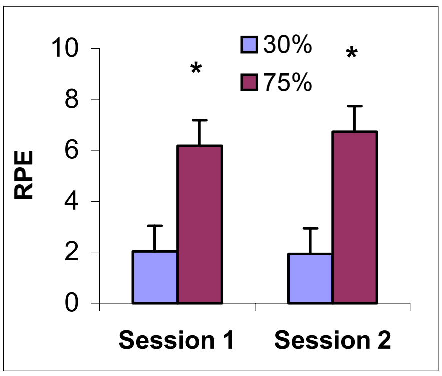

Figure 4. Average RPE for the squat exercise during each testing session. * denotes significant differences between 30% and 75% exercise bouts.

A test for reliability of the session RPE to predict the same value across two different trials of the same intensity was performed. The ICC was 0.95 with the 95% confidence interval of 0.90-0.97.

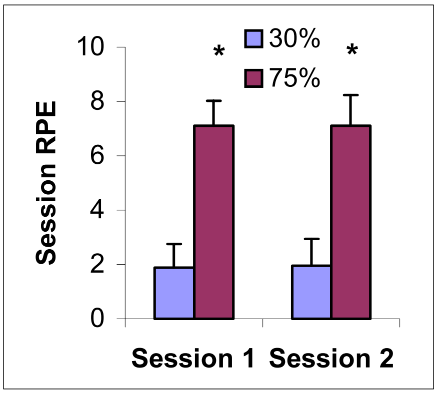

Figure 5. Session RPE data for the low intensity and high intensity sessions. * denotes significant differences between 30% and 75% exercise bouts.

There were no significant correlations between salivary cortisol levels immediately post or 30 minutes post exercise and measures of RPE (both average RPE and session RPE). There were also no significant correlations between salivary cortisol levels and load.

DISCUSSION

Earlier studies have shown that resistance exercise has a significant effect on cortisol levels following exercise (Mulligan et al., 1996; Nindl et al., 2001). The present study showed that salivary cortisol responses were significantly different immediately post exercise between the low intensity and high intensity exercise sessions (145%). Immediately following the high intensity acute resistance exercise bout there was a significant elevation of 97% in salivary cortisol from baseline. This increase in salivary cortisol was significantly larger than the cortisol response for the low intensity resistance exercise session.

Salivary cortisol levels have been shown to increase following acute exercise with the response dependent on the intensity and duration of activity (Lac and Berthon, 2000; Jacks et al., 2002). To our knowledge there are no studies that have measured salivary cortisol following different intensities of resistance exercise. However, there is limited research investigating salivary cortisol responses to resistance exercise. Salivary cortisol provides a stress free, non-invasive procedure (Vining and McGinley, 1987) that avoids additional stress caused by venipuncture (Lac et al., 1993). Salivary cortisol may also be a better measure of adrenocortical function as it represents more accurately the level of unbound cortisol (Vining et al., 1983).

In the present investigation we showed that a high intensity bout of resistance exercise significantly increases the level of salivary cortisol. This in agreement with the majority of studies that have shown that high intensity resistance exercise elevates serum cortisol (Mulligan et al., 1996; Fry et al., 2000; Nindl et al., 2001; Smilios et al., 2003). A recent study by Smilios et al. (2003) showed that different resistance exercise protocols produce different hormonal response patterns depending on the number of sets that are performed.

Previous research has shown that the volume of resistance exercise as measured by the number of sets performed, affects the hormonal concentrations. Studies have demonstrated that performing three sets of each exercise results in higher levels of cortisol, testosterone and growth hormone compared to one set of each exercise (Mulligan et al., 1996; Gotshalk et al., 1997). Our data also confirmed that salivary cortisol levels were significantly elevated when a higher volume of work was performed (6 sets versus 3 sets). In addition to the number of sets performed, another factor that may be affect the salivary cortisol response is the training status of the subjects. The majority of subjects in the present study were only recreationally trained, as reflected by the average squat 1RM to bodyweight ratio (1.62 for men and 1.16 for women). It has been suggested that multiple set workouts are more effective for well trained individuals (ACSM, 2002) and hormonal responses are influenced by the training status of the individual (Fry et al., 2000). For the present study there was a strong correlation ($r = .54$, $p = 0.08$) between the squat 1RM to bodyweight ratio and the percentage change in salivary cortisol concentrations from pre- to post the exercise bout. Although this was not a significant relationship it does suggest that the training status of the subjects is related to the hormonal response. There was however a wide range of individual responses of salivary cortisol to the different intensities of resistance exercises, as demonstrated by the large standard deviations (Figure 1). In addition, the inclusion of both men and women in the present study could provide a confounding factor. There was no significant differences between the men and women in the study for both salivary cortisol responses and session RPE values. However, this could have contributed to the large variation of salivary cortisol responses as there may have been variation in the menstrual status of the female subjects. We attempted to control for the time of day by having the subjects complete their testing for all sessions at the same time. All testing was conducted in the morning as salivary cortisol has been shown to have a circadian rhythm (Thuma et al., 1995; Raff et al.1998).

The second purpose of this study was to evaluate the reliability and effectiveness of the session RPE method to rate an overall resistance training session using multi-set exercises. Based on the data, the session RPE method appears to be a reliable method of quantifying resistance training intensities. We have previously shown that the session RPE method is a reliable measure for evaluating single-set exercise bouts (Day et al., in press). However, multiple set workouts have been recommended for optimal development of strength and power (ACSM, 2002). Therefore, we felt it was important to determine the reliability of this measure with multiple set training. This was the rationale for using two sessions of each exercise intensity. There was a significant difference between the session RPE values for each intensity for the two exercises (bench press and squat). The average RPE value and session RPE value for the bench press exercise were also significantly different. For the squat exercise however, no significant difference was found between average RPE value and session RPE value.

These findings are similar to a previous study conducted in our laboratory (Day et al., in press). Another study conducted recently in our laboratory compared session RPE during easy, moderate, and high intensity resistance training to session RPE during comparable intensities of steady state aerobic exercise on a cycle ergometer (Sweet et al., in press). Session RPE and the mean RPE all increased as the % 1-RM increased despite a decrease in repetitions and total workload. The results of this series of studies supports the idea that the session RPE is a valid method for quantifying the intensity of resistance training, and is generally comparable to aerobic training. The difference between the bench press and squat exercises for mean RPE versus session RPE is similar to our previous findings, in that it appears that RPE measurements taken after each set varied widely depending on the type of resistance exercise being performed, ie. large muscle mass exercises versus small muscle mass exercises (Day et al., in press; Sweet et al., in press). Many factors could have influenced variations in RPE measurements such as motor unit recruitment and energy expenditure.

In the present study we used an exercise protocol designed to clearly delineate between higher volume, high intensity bouts of exercise and a low intensity workout to investigate the hormonal response and perceived exertion. However, there was no attempt to equate the exercise protocols for total work performed, although the rest periods were the same for both protocols. It is also important to note that the exercise bouts used in the present study do not necessarily reflect the type of workout that would be used traditionally by exercisers. Future studies could investigate the effect of exercise protocols designed to improve maximum strength, hypertrophy and power on the hormonal responses, in addition to session RPE.

Other researchers have investigated perceived exertion and resistance exercise (Gearhart et al., 2001; 2002). Resistance training consists of a complex milieu of variables including sets, repetitions, rest periods and type of exercise performed. Therefore, resistance exercise represents a unique mode to study perceived exertion and hormonal responses. The RPE values for each set were taken in addition to the session rating. The purpose of taking the set RPE values was to further familiarize the subjects with rating their perceived effort on the modified CR-10 scale. We believed this would increase the accuracy of the session RPE value. This study provides further evidence validating the findings of Gearhart et al. (2002) and Day et al. (in press), where fewer repetitions of a heavier resistance was perceived to be more difficult than performing more repetitions of a lighter resistance. Training volume in resistance exercise is a composite of the number of sets, number of repetitions and the amount of resistance lifted. This is an important difference from non resistance type of training where the total duration of exercise in minutes is the appropriate duration measure. Because of the long periods of recovery required in resistance training, particularly in high intensity resistance training, time per se is probably an inappropriate measure of training volume. Previous studies by Day et al. (in press), Gearhart et al. (2001) and Sweet et al. (in press) have shown that RPE is most influenced by exercise intensity and not by the volume of exercise being performed. Further research is required to investigate the role of training volume during resistance exercise, on both RPE and salivary hormonal responses.

CONCLUSIONS

In conclusion, there was a significant difference between the salivary cortisol responses immediately following the high and low intensity exercise protocols. This study has demonstrated that salivary measures of cortisol can be used to delineate between high and low intensity workouts. The results of this study have also shown that session RPE is a reliable and useful tool of measuring the intensity of a resistance training session. This scale would be a beneficial tool for researchers, strength coaches, recreational weightlifters, and athletes as they strive to rate the work intensity of a resistance training session. Overall, the session RPE scale was shown to be a reliable tool to quantify work of low intensity and high intensity workouts.

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KEY POINTS

- The present study showed that salivary cortisol responses were significantly different immediately post exercise between the low intensity and high intensity exercise sessions
- Salivary measures of cortisol can be used to delineate between high and low intensity resistance exercise bouts.
- The session RPE method appears to be a reliable method of quantifying resistance exercise