A Comparison of Workload Quantification Methods in Relation to

Physiological Responses to Resistance Exercise

Workload Quantification in Resistance Exercise

ABSTRACT

The purpose of this study was to (a) assess the usefulness of volume load (VL), session RPE (SRPE), RPE load (RPEL), and a modified RPEL (RPEL-2) to estimate internal load from resistance exercise (RE), and (b) to further assess the interactions between SRPE, VL, and RE intensity. Twelve healthy males (25 ± 4 years) completed RE sessions at 55%, 70%, and 85% 1RM. VL, SRPE, RPEL and RPEL-2 for each session were calculated, compared, and correlated with change values (Δ) for blood lactate and salivary cortisol. There were substantial increases in all measures of training load with progressive decreases in %1RM. There were clear substantial increases in Δ lactate and Δ cortisol following RT at 55% 1RM when compared to 70% and 85%. Within-subject correlations with Δ cortisol were small with SRPE (r = 0.25; 90% confidence limits; ±0.32), RPEL (r = 0.23; ±0.32) and RPEL-2 (r = 0.19; ±0.32) and trivial for VL (r = 0.01; ±0.28). Correlations with Δ lactate were moderate with VL (r = 0.42; ±0.29) and RPEL-2 (r = 0.38; ±0.29), and small with SRPE (r = 0.25; ±0.32) and RPEL (r = 0.25; ±0.32). Correlation between SRPE and VL was large (r = 0.55; ±0.25). Whilst Δ lactate and Δ cortisol did not follow the same trends as measures of workload, VL may be superior to estimate internal load from RE, particularly when measured via Δ lactate. When viewing training load globally RPEL-2 may offer the greatest advantage. Finally, our results suggest that SRPE appears to be more closely related to VL than %1RM.

Key words: Training load, internal load, session RPE, RPE load, global load

INTRODUCTION

It is widely acknowledged that internal physiological responses induced primarily from training, but also from non-training variables, are responsible for the total physiological stress placed on athletes (37,38,23). Referred to as internal load (2,28), this total physiological stress is viewed as being the determinant of whether an athlete's adaptations are positive or negative and whether the outcome is performance enhancement, overtraining, illness, or injury (25,18). This makes the quantification and monitoring of internal load vital for ensuring appropriate manipulation of training to induce desirable responses and adaptations (16,23). Despite this, training is often monitored and quantified using outcome measures such as distance travelled or the total volume of load lifted with such variables often referred to as external load (45,31). Whilst external load clearly provides important information (45), it may not accurately reflect internal load therefore making the prediction and modification of physiological outcome and adaptation very difficult.

Although methods of measuring training load from an external perspective (e.g. global positioning, volume load) and internal perspective (e.g. heart rate, blood lactate, hormones) are plentiful, a method to monitor internal load across all training modes and intensities is desirable. One such method reported across the literature (15,9,44,36) is RPE load (RPEL) which multiplies session RPE (SRPE), as a measure of training intensity, with session duration, as a measure of training volume, to provide a training load value. Previous research has

validated RPEL for quantifying internal load across a variety of training modes and sports (15,9,44,36).Despite this, researchers are yet to fully agree on the efficacy of SRPE to estimate resistance exercise (RE) intensity, with some claiming that SRPE may actually be more closely related to the volume load (VL) of an RE session (31,41,48,11,35,46). Additionally the use of RPEL to quantify internal load for RE has yet to be fully assessed (46,48,11,35), with the external measure of VL often preferred. Whilst VL is an excellent method to monitor external load (33,19), there is little evidence of its effectiveness to estimate internal load. Additionally the VL equation does not allow it to be used globally across all modes of training.

As HR based methods may not accurately reflect internal load during RE (16), it is suggested that SRPE, RPEL and VL should be assessed against the physiological responses associated with intensity and workload in RE. Blood lactate has previously been linked to intensity (%1RM) and total work across various training modes including RE (6,34,40). Cortisol is also altered by various RE training modes and strongly associated with changes in intensity, volume, and workload (35,10,24,1,47,51,42), and may also reflect stress accumulated outside of training (29,14,8,20). Therefore, lactate and cortisol are appropriate variables against which to compare internal workload quantification methods.

Because RE is programmed in terms of sets, repetitions, and rest intervals, and since rest intervals in RE are often extremely large in comparison to actual work, the use of total session duration to quantify training volume may not be appropriate (35). Consequently the use of a modified version of RPE L, which

discards the summation of rest intervals, therefore accounting only for the total duration of time that work was actually being performed (RPEL-2), warrants assessment.

The aims of this study were therefore to (a) assess the usefulness of VL, SRPE, RPEL, and RPEL-2 to estimate internal load from RE, and (b) to further assess the interactions between SRPE, VL, and RE intensity.+.

METHODS

Experimental Approach to the Problem

Subjects each completed three RE protocols using 85%, 70%, and 55% 1RM in a counterbalanced, randomised crossover design. VL, SRPE, RPEL and RPEL-2 were subsequently calculated to allow cross method comparison across all RE protocols. For each protocol subjects provided blood lactate and salivary cortisol samples immediately pre, immediately post, and thirty minutes post RE. These values were subsequently used to measure the relationships between the workload quantification methods and the internal physiological response.

Subjects

Twelve physically active males (aged 25 ± 4y; height 180 ± 7 cm; mass 77 ± 10 kg), with at least 1 year RE experience, were recruited to participate in this study. All reported participating in an RE programme of at least 2 sessions per week for the twelve months prior to the study. All were also asked to conform to the following instructions for each protocol: consume the same diet in the 24 hours prior to participation, refrain from eating 3-4 hours prior to participation, consume only water during and for 30 minutes post participation, and abstain

from exercise, alcohol, and caffeine for at least 48 hours before each session. Participants confirmed that they had adhered to the instructions prior to commencing each session, although diet records were not taken. Subjects were screened using a medical questionnaire to confirm adequate health and all completed informed consent. Ethical approval was granted by Teesside University Ethics Committee. **Procedures**

One week prior to starting RE protocols, participants completed 5RM testing in line with recommended procedure (4), for each resistance exercise used Table 1). 5RM testing was used in preference to 1RM testing in order to account for differences in training experience between participants, therefore reducing safety concerns and the impact of participant anxiety on test results. The tests were performed in an alternate lower body / upper body fashion in order to reduce the impact of acute local cumulative fatigue on test results. Test order was back squat, chest press, deadlift, bent over row, and Romanian deadlift. All tests were preceded by a standardised warm up, firstly performing a set of 10 repetitions approximately 50% of estimated 5RM. Participants then completed 10 repetitions and 7 repetitions at 70% and 90% of estimated 5RM, respectively. Testing was then completed within 3-5 attempts per exercise, using increases of 5-10% if the previous set was completed successfully. A set was successfully completed when all repetitions were completed with the appropriate technique. Where a set was not successfully completed the load was reduced by 2.5-5% for the subsequent set. A rest period of 3 minutes was given between each attempt. Technique standardisation for each exercise was in line with recommendations (4), with the exception of the Romanian deadlift. Technique for this exercise was standardised using the following criteria. Start

with feet between hip and shoulder width apart; keep chest up, back straight, and slight bend in knees; keep bar close to body lowering barbell to just below kneecap; keeping back straight, stand up and fully extend hips. This technique was used due to safety concerns regarding the lumbar spine when lowering the barbell to the floor without appropriate posterior chain flexibility. Individual loads for each session and exercise were calculated based on 1RM's estimated from the 5RM tests (4). Participants were also familiarised with blood lactate and salivary cortisol sampling techniques, the SRPE scale. Due to participant, facility, and equipment availability, participants worked in two subgroups training from 19.00–21.00 and 09.00–11.00 respectively. Each participant trained at the same time of day for each session to account for the circadian rhythm of cortisol (43). Following a standardised warm up, each session was completed using three sets of each exercise performed in the same order, with two minutes rest between sets. As Fisher *et al* (13) asserted that intensity in its truest sense refers to the level of effort applied at a given load, it is argued that studies assessing workload at different percentages of 1RM should control set endpoint according to levels of relative effort at each given workload. To that end a set was complete when the participant perceived that they were 1-2 repetitions from volitional exhaustion. Protocols were performed with seven days of recovery to minimise the impact of cumulative fatigue.

Blood was collected via finger venepuncture and analysed for lactate using a YSI 2300 analyser (YSI UK ltd, Hampshire, UK). Saliva was taken via Sarstedt salivette and analysed for cortisol using Salimetrics High Sensitivity Salivary Cortisol Enzyme Immunoassay Kit and a Labsystems Multiscan Microplate Reader, (Labsystems, Helsinki, Finlad). Values were subsequently used to

calculate a delta (change; Δ) score for each participant for lactate and cortisol by subtracting the pre values from the greatest of the post and post30 values. Salivary cortisol has been found to be closely related to serum unbound cortisol (r = 0.93) (39), with previous studies reporting its highest point of elevation to be at 30 minutes post exercise (50,47). To ensure reliability of measures, intra-tester test-retest reliability was completed using samples obtained from the 12 participants during 5RM testing. Results were analysed using coefficient of variation (CV) and intra-class correlation (ICC) with CV calculated as 5.6% for salivary cortisol and 2.1% for blood lactate, and ICC values of 0.98 and 0.90, respectively.

SRPE was recorded at post30 for each session by asking participants "how was your workout" (16), whilst time per set and reps completed were recorded throughout each session by a randomly assigned training partner. Values were then used to calculate RPEL, RPEL-2, and VL (19).

*** Insert table 1 about here***

Statistical Analyses

Data are presented as the mean ± SD. Using a custom-made spreadsheet (21), all data were log transformed and then back transformed to obtain the percent difference, with uncertainty of the estimates expressed as 90% confidence limits, between training loads (VL, SRPE, RPEL, RPEL-2) for the three resistance training protocols (55%, 70%, 85% 1RM). This is the appropriate method for quantifying changes in athletic performance (22). Inference was then based on the disposition of the confidence interval for the mean difference to the smallest worthwhile effect; the probability (percent chances) that the true

population difference between RE sessions was substantial (>0.2 SDs) or trivial was calculated as per the magnitude-based inference approach (5). These percent chances were qualified via probabilistic terms assigned using the following scale: <0.5%, most unlikely; 0.5–5%, very unlikely; 5–25%, unlikely; 25–75%, possibly; 75–95%, likely; 95–99.5%, very likely; >99.5%, most likely (22). A within-subject design was used to determine if high workload load scores (VL, SRPE, RPEL, RPEL-2) were associated with greater changes in post-session cortisol and blood lactate. This is the appropriate method as it permits the analysis of within-subject changes by removing between-subject differences (7). Within-subject correlations were therefore calculated between the participants' VL and SRPE scores, and Δ cortisol and Δ lactate with the measures training load following the three resistance training protocols (55%, 70%, 85% 1RM). Confidence limits (90%) for the within-participant correlations were calculated as per Altman and Bland (3). The following scale of magnitudes (22) was used to interpret the magnitude of the correlation coefficients: <0.1, trivial; 0.1-0.3, small; 0.3-0.5, moderate; 0.5-0.7, large; 0.7-0.9, very large; >0.9, nearly perfect.

RESULTS

Insert table 2 about here

Descriptive data for the three resistance training protocols are presented in Table 1. We observed clear, substantial increases in all measures of training load (VL, SRPE, RPEL and RPEL-2) with progressive decreases in exercise intensity, as determined by % of 1RM (Table 2). Clear, substantial increases

were also recorded for the Δ lactate and Δ cortisol following the 55% 1RM protocol when compared to the 70% and 85% 1RM protocols. The differences for the Δ lactate and Δ cortisol following the 70% 1RM protocol when compared to the 85% 1RM protocols were less clear.

There were small correlations between SRPE (r = 0.25; 90% confidence limits; $\pm$0.32), RPEL (r = 0.23; $\pm$0.32) and RPEL-2 (r = 0.19; $\pm$0.32) with Δ cortisol and a trivial correlation between VL with Δ cortisol (r = 0.01; $\pm$0.28). Moderate correlations were shown between VL (r = 0.42; $\pm$0.29) and RPEL-2 (r = 0.38; $\pm$0.29) with Δ lactate, and small correlations between SRPE (r = 0.25; $\pm$0.32) and RPEL (r = 0.25; $\pm$0.32) with Δ lactate. There was also a large correlation between SRPE and VL (r = 0.55; $\pm$0.25).

*** Insert table 3 about here ***

DISCUSSION

The aims of this study were to (a) assess the usefulness of VL, SRPE, RPEL, and RPEL-2 to estimate internal load from RE, and (b) to further assess the interactions between SRPE, VL, and RE intensity. This is the first study to assess the use of SRPE, VL, RPEL, and RPEL-2 to estimate internal load from RE at different intensities, and further adds to the literature regarding the interaction between SRPE, VL and RE intensity. All measures of workload substantially differentiated between RE at different intensities, with greater workload values at 55% 1RM and lower workload values at 85% 1RM. Our participants also exhibited substantially higher internal loads from RE at 55%

1RM compared to 70% and 85% 1RM, although the lack of substantial difference between RE at 70% and 85% shows that internal responses did not follow the same trends as measures of workload. The findings also suggest that measures of workload, particularly VL and RPEL-2, may be related to internal load when measured via change in lactate, but not when measured by change in salivary cortisol. Finally, our results showed that SRPE did not reflect intensity when expressed as %1RM, although it was largely associated with VL.

Greater workloads were achieved at lower intensities and lower workloads.at higher intensities, for all measures of workload. This suggests that with set endpoint and inter-set rest standardised, RE at a lower %1RM may result in greater internal loads. This was somewhat supported by the changes in cortisol and lactate, which were also greatest at 55% 1RM. In contrast to measures of workload, the less clear differences in cortisol and lactate change from RE at 70% 1RM compared to 85% 1RM make it difficult to make any strong inferences about the differences in physiological response between these sessions. This perhaps suggests that the between intensity differences in measures of workload may have been contributed to by physiological variables not measured in the present study. This observation is supported by the small and trivial correlations between measures of workload and cortisol. The moderate positive correlations seen from VL and RPEL-2 with lactate suggested that these measures of workload may moderately reflect internal load from RE at different intensities. The small correlations seen from SRPE and RPEL with lactate suggest these may be less able to reflect internal load from RE at different intensities.

Due to the lack of previous research assessing the usefulness of VL, RPEL, and RPEL-2 to quantify workload from RE, comparisons to the current study are difficult. McBride *et al* (2009) assessed the use of various workload quantification methods from hypertrophy, strength, and power protocols, although inferences about their ability to estimate internal load could not be made as none of these methods were compared to any measure of internal physiological response.. Regardless, the authors reported greater VL values as a result of the strength protocol, although this could be explained by the large differences in sets and reps performed between protocols. Additionally inter-set rest period and set endpoint relative to effort were not accounted for, meaning the results cannot truly be used to assess the ability of VL to differentiate between RE at different intensities. Our results were in-line those of Pritchett *et al* (2009) who reported that VL was greater from a session performed at 60% compared to 90% 1RM. The authors standardised set endpoint, having all participants perform sets to volitional exhaustion. They also standardised inter-set rest period, therefore reducing the impact of further confounding variables on the results.

Previous research has reported that in RE lactate and cortisol responses tend to be greater from protocols utilising the greatest VL, lowest %1RM, and the shortest rest periods (47,34,10). We report similar findings, although perhaps due to the standardised inter-set rest periods and standardised set end point, smaller between intensity differences were evident in the current study. Additionally the difference in lactate and cortisol responses between RE at 70% and 85% appeared smaller and less clear in the current study than previously reported. The current study's standardisation of set endpoint and inter-set rest

period during the current study again may be able to account for these inconsistencies.

The lack of strength in correlations between measures of workload and salivary cortisol suggests that these measures do not accurately reflect cortisol response to RE. Similar findings were reported by McGuigan *et al* (2004), although only between SRPE and cortisol. Previous research has also shown that cortisol responses from RE are greater in fitter individuals (32,17). It is therefore possible that the heterogeneity in strength levels observed in the present study may have been an important influencing factor on the relationship between salivary cortisol and measures of workload. (Table 1). As SRPE and RPEL have previously been used to accurately reflect internal load via other physiological measures from other training modes (15,9,42,35), it is possible that salivary cortisol is not an accurate measure of internal load from RE. Previous research has reported that RPE can be influenced by a host of psycho-physiological variables (12), possibly explaining why the relationships found in the current study were not stronger. Specific to RE, previous research has reported RPE to be related to neuromotor activity as measured by electromyography (EMG) (26,27). Additionally other researchers have reported a variety of other neuromuscular, metabolic and hormonal measures to be altered from RE (10, 26, 34, 42, 47). It is therefore possible that measuring alternative physiological variables may have resulted in greater relationships with our measures of workload, allowing a greater insight into their effectiveness as measures estimators of internal load.

The relationship between VL and lactate appeared similar to those reported by previous researchers (34,47), with lactate response suggested to largely be a product of the total work encountered during RE. Although previous research has failed to assess the relationship of the lactate response to RE with SRPE, RPEL, and RPEL-2, the results of the current study suggested that RPEL-2 may be the superior of these three measures, closely behind VL. This is possibly due to its ability to account for the total time working rather than the full session duration, which may be an important consideration when assessing training protocols with long rest periods (35). As the correlation was close to that observed between lactate and VL, RPEL-2 may be similarly capable of estimating internal load, with the advantage of also being usable in other training modes. This suggests that RPEL-2 may provide a useful global workload quantification method, although the moderate correlation again suggests that other physiological variables may have also contributed to the RPEL-2 values.

SRPE did not reflect intensity when expressed as %1RM, although it did have a large relationship with VL. The results of the current study are supported by Pritchett *et al* (2009) who reported that SRPE was largely associated with VL, even when the higher VL values were achieved from session performed at the lowest %1RM. Lodo *et al* (2012) further supported these findings with a two part experimental design. In the first experiment participants each performed RE in a strength orientated session (10 sets of 4RM), a hypertrophy session (8 sets of 8RM), and an endurance session. Significant positive correlations were found between VL and SRPE with the highest values achieved from RE at higher intensities. In the second experiment participants each performed RE sessions

at 50% 1RM and 75% 1RM with VL matched between sessions. Significant positive correlations were again found between SRPE and VL and no significant differences were found between intensities for SRPE.

Despite this, other studies have reported that SRPE is a valid and reliable method to monitor RE intensity and different types of RE, with SRPE tending to reflect intensity when expressed as %1RM (30,48,11,35,46). There are several possible explanations for these differences. Firstly, all of these studies failed to control or account for VL. Without this being controlled or accounted for it is not possible to clearly infer whether the SRPE values may have been more strongly associated with VL than %1RM, although based on the findings of the current study, and the similar findings from Pritchett *et al* (2009) and Lodo *et al* (2012), this could be a possibility. Interestingly, retrospective analysis of the methods from those studies showing a relationship between %1RM and SRPE, does allow an alternative version of VL (AVL) to be calculated for the RE sessions at all intensities performed. AVL multiplies sets × reps × the %1RM values for each session, rather than using the absolute load values usually used (18). Reviewing the results using these values reveals variable findings. In two of the four studies AVL followed the same trend as SRPE (35, 30), whilst in the other three (48,11,46) AVL values were inverse to SRPE. Despite this, further analysis of the methods reveal that in these 3 studies RE was performed at 90% 1RM using 4-5 reps, 70% 1RM using 10 reps, and 50% 1RM using 15 reps. As previous authors have asserted that intensity in its truest sense refers to the level of effort applied at a given load (13), it is of interest to review these results according to this premise. Utilising RM prediction tables (4) and equations (43) reveals that performing 4-5 reps at 90% 1RM, 10 reps at 70%

1RM, and 15 reps at 50% 1RM, equates to approximately 100%, 85%, and less than 70% of an estimated maximal effort at each given load, respectively. Indeed, looking across all studies discussed it can be seen that when estimated relative effort was similar between sessions at a different %1RM, VL or AVL was associated with or followed a similar trend to SRPE. When VL or AVL was equal or inverse to SRPE, estimated relative effort followed a similar trend to SRPE. In contrast when VL or AVL was equal or inverse to SRPE, with set end point standardised in terms of relative effort, %1RM did not follow the same trends as SRPE. Given these facts and that SRPE asks participants the broad question "how hard was your session" rather than "how intense was your session in relation to your 1RM", it is possible that VL, and the level of effort applied at a given %1RM, may have a greater influence on SRPE than %1RM alone. . Based on the current findings, and those of previous studies, it is likely that SPRE in RE is affected by more than simply %1RM with VL likely a contributory factor, and relative effort at a given load also potentially playing a role. Future studies may look to further assess exactly how these variables interact with each during RE. .

PRACTICAL APPLICATIONS

Although all measures of workload were able to differentiate between RT at different intensities, VL and RPEL-2 may be superior for estimating the internal load achieved. Therefore when RE is the only training mode VL may offer the best of the four methods to monitor workloads. When other training modes are being utilised RPEL-2 may be the method of choice, although more research

into its use during RE, and other training modes, is required before it can be broadly recommended. It may also be of interest to practitioners and researchers to monitor intensity using relative effort at a given load rather than a percentage of maximal effort, although this again needs more research before being broadly recommended. There were several limitations to the current study. As set-endpoint in the current study was regulated by individual perception, potential discrepancies in effort across participants may have affected the results. Furthermore, participants were required to adjust load for their partner between sets which would likely have influenced physiological responses and RPE values. As previous research has reported the benefit of using RPEL and SRPE across a variety of training modes, the findings of the current study should not be interpreted as reason to no longer utilise them. Despite this, the current findings do suggest that more research in to their usefulness across training modes utilising a variety of methodological approaches is warranted, with a particular focus on RE.

REFERENCES

1. Ahtiainen, J., Pakarinen, A., Kraemer, W. and Häkkinen, K. Acute Hormonal and Neuromuscular Responses and Recovery to Forced vs. Maximum Repetitions Multiple Resistance Exercises. *Int J Sports Med* 24: 410-418, 2003

2. Alexiou, H. and Coutts, A. A comparison of methods used for quantifying internal training load in women soccer players. *Int J Sports Physiol Perf* 3: 320-330, 2008

3. Altman, D. and Bland, M. How to obtain the confidence interval from a P value. *BMJ.* 343: 2090, 2011

4. Baechle, T. and Earle, R. *Essentials of Strength Training and Conditioning*. Champaign, IL: Human Kinetics, 2008

5. Batterham, A. and Hopkins, W. Making Meaningful Inferences About Magnitudes. *Int J Sports Physiol Perf* 1: 50-57, 2006

6. Borg, G., Hassmen, P. and Lagerstrom, M. Perceived exertion related to heart rate and blood lactate during arm and leg exercise. *Eur J Appl Physiol Occup Phys* 56: 679-685, 1987

7. Bland, J, Altman D. Calculating correlation coefficients with repeated observations: Part 1-correlation within subjects. *BMJ*: 310, 1995

8. Burke, H., Davis, M., Otte, C. and Mohr, D. Depression and cortisol responses to psychological stress: A meta-analysis. *Psychoneuroendocrinology*. 30: 846-856, 2005

9. Coutts, A., Rampinini, E., Marcora, S., Castagna, C. and Impellizzeri, F. Heart rate and blood lactate correlates of perceived exertion during small-sided soccer games. *J Sci Med Sport* 12: 79-84, 2009

10. Crewther, B., Cronin, J., Keogh, J. and Cook, C. The Salivary Testosterone and Cortisol Response to Three Loading Schemes. *J Strength Cond Res* 22: 250-255, 2008

11. Day, M., McGuigan, M., Brice, G. and Foster, C. Monitoring Intensities During Resistance Training Using a Session RPE Scale. *J Strength Cond Res* 18: 353-358, 2004

12. Eston, R. Use of Ratings of Perceived Exertion in Sports. *Int J Sports Physiol Perf* 7: 175-182, 2012

13. Fisher, J., Steele, J., Bruce-Low, S. and Smith, D. Evidence based resistance training recommendations. *Med Sport* 15: 147-162, 2011

14. Follenius, M., Brandenberger, G., Oyono, S. and Candas, V. Cortisol as a sensitive index of heat-intolerance. *Physiol Behav* 29: 509-513, 1982

15. Foster, C. Monitoring training in athletes with reference to overtraining syndrome. *Med Sci Sports Exerc* 30: 1164-1168, 1998

16. Foster, C., Florhaug, J., Franklin, J., Gottschall, L., Hrovatin, L., Parker, S., Doleshal, P. and Hodge, C. A New Approach to Monitoring Exercise Training. *J Strength Cond Res* 15: 109-115, 2001

17. Fry, A., Kraemer, W., Stone, M., Koziris, L., Thrush, J. and Fleck, S. Relationships between serum testosterone, cortisol and weightlifting performance. *J Strength Cond Res* 14: 338-343, 2000

18. Fry, R., Morton, A. and Keast, D. Overtraining in athletes: an update. *Sports Med* 12: 32-65, 1991

19. Haff, G. Quantifying Workloads in Resistance Training: A Brief Review. *Professional Strength and Conditioning*. 19: 4-13, 2010

20. Hansen, A., Garde, A. and Persson, R. Sources of biological and methodological variation in salivary cortisol and their impact on measurement among healthy adults: a review. *Scand J Clin Lab Invest.* 68: 448-458, 2008

21. Hopkins, W. Spreadsheets for analysis of controlled trials with adjustment for a predictor. *Sportscience* 10: 46-50, 2006 (sportsci.org/2006/wghcontrial.htm)

22. Hopkins, W., Marshall, S., Batterham, A. and Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*. 41: 13-23, 2009

23. Impelizzeri, F., Rampinini, E. and Marcora, S. Physiological assessment of aerobic training in soccer. *J Sports Sci* 23: 583 – 592, 2005

24. Jacks, D., Sowash, J., Anning, J., McGloughlin, T. and Andres, F. Effect of exercise at three exercise intensities on salivary cortisol. *J Strength Cond Res* 16: 286-289, 2002

25. Kentta, G. and Hassmen, P. Overtraining and Recovery. *Sports Me*d 26: 1-16, 1998

26. Lagally, K., Robertson, R., Gallagher, K., Goss, F., Jakicic, J., Lephart, S., McCaw, S. and Goodpaster, B. Perceived exertion, electromyography, and blood lactate during acute bouts of resistance exercise. *Med Sci Sports Exerc* 34: 552-559, 2002

27. Lagally, K., McCaw, S., Young, G., Medema, H. and Thomas, D. Ratings of Perceived Exertion and Muscle Activity During the Bench Press Exercise in Recreational and Novice Lifters. *J Strength Cond Res* 18: 359-364, 2004

28. Lambert, M. and Borresen, J. Measuring Training Load in Sports. *Int J Sports Physiol Perf* 5: 406-411, 2010

29. Leproult, R., Copinschi, G., Buxton, O. and Van Cauter, E. Sleep loss results in an elevation of cortisol levels the next evening. *Sleep* 20: 865-870, 1997

30. Linz-Filho, O., Robertson, R., Farah, B., Rodrigues, S., Cyrino, E. and Ritti-Dias, R. Effects of Exercise Intensity on Rating of Perceived Exertion During

a Multiple-Set Resistance Exercise Session. *J Strength Cond Res* 26:466-472, 2012

31. Lodo, L., Moreira, A., Zavanela, P., Newton, M., McGuigan, R. and Aoki, M. Is there a relationship between the total volume of load lifted in bench press exercise and the rating of perceived exertion?. *J Sports Med Phys Fitness* 52: 483-488, 2012

32. Marthur, D., Toriola, A. and Dada, O. Serum cortisol and testosterone levels in conditioned male distance runners and non-athletes after maximal exercise. *J Sports Med* 26: 242-250. 1986

33. McBride, J., McCaulley, G., Cormie, P., Nuzzo, J., Cavill, Michael, J. and Triplett, T. Comparison of Methods to Quantify Volume During Resistance Exercise. *J Strength Cond Res* 23: 106-110, 2009

34. McCaulley, G., McBride, J., Cormie, P., Hudson, M., Nuzzo, J., Quindry, J. and Triplett, T. Acute hormonal and neuromuscular responses to hypertrophy, strength and power type resistance exercise. *Eur J Appl Physiol* 105: 695-704, 2009

35. McGuigan, M., Egan, A. and Foster, C. Salivary Cortisol Responses and Perceived Exertion During High Intensity and Low Intensity Bouts of Resistance Exercise. *J Sports Sci Med*. 3: 8-15, 2004

36. Milanez, V., Spiguel Lima, M., Gobatto, C., Perandini, L., Nakamura, F. and Ribeiro, L. Correlates of session-rate of perceived exertion (RPE) in a karate training session. *Sci Sports* 26: 38-43, 2011

37. Morgan, P., Costill, D., Flynn, G., Raglin, J. and O'Connor, P. Mood disturbance following increased training in swimmers. *Med Sci Sports Exerc* 20: 408-414, 1998

38. Morgan. P., Brown, D., Raglin, J., O'Connor, P. and Ellickson, K. Psychological monitoring of overtraining and staleness. *British Journal of Sports Med* 21: 107-114, 1987

39. O'Connor, P. and Corrigan, D. Influence of short-term cycling on salivary cortisol levels. *Med Sci Sports Exerc* 19, 224-228, 1987

40. Oliver, S., Costa, R., Laing, S., Bilzon, J. and Walsh, N. One night of sleep deprivation decreases treadmill endurance performance. *European Eur J Appl Physiol* 107: 155-161, 2009

41. Pritchett, R., Green, J., Wickwire, P., Pritchett, K. and Kovacs, M. Acute and session RPE responses during resistance training: Bouts to failure at 60% and 90% of 1RM. *S Afr J Sports Med* 21: 23-26, 2009

42. Ratamess, N., Kraemer, W., Volek, J., Maresh, C., Van Heest, J., Sharman, M., Rubin, M., French, D., Vescovi, J. and Silvestre, R. Hattfield, D., Fleck, S. and Deschenes, M. Androgen receptor content following heavy resistance exercise in men. *J Steroid Biochem Mol Biol* 93: 35-42. 2005

43. Reynolds, J., Gordon, T. and Roberg, R. Prediction of 1 repetition maximum strength from multiple repetition maximum testing and anthropometry. *J Strength Cond Res* 20: 584–592, 2006

44. Rodriguez-Alonso, M., Fernandez-Garcia, B., Perez-Landaluce, J. and Terrados, N. Blood lactate and heart rate during national and international women's basketball. *J Sports Med Phys Fitness* 43: 432-436, 2003

45. Scott, T., Black, C., Quinn, J. and Coutts, A. Validity and reliability of the session-RPE method for quantifying training in Australian football: a comparison of the CR10 and CR100 scales. *J Strength Cond Res* 27: 270-276, 2013

46. Singh, F., Foster, C., Tod, D. and McGuigan, M. Monitoring Different Types of Resistance Training Using Session Rating of Perceived Exertion. *Int J Sports Physiol Perf* 2: 34-45, 2007

47. Smillios, I., Pilianidis, T., Karamouzis, M. and Tokmakidis, S. Hormonal Response after Various Resistance Exercise Protocols. *Med Sci Sports Exerc*. 35: 644-654, 2003

48. Sweet, T., Foster, C., McGuigan, M. and Brice, G. Quantitation of Resistance Training Using the Session Rating of Perceived Exertion Method. *J Strength Cond Res* 18: 796-802, 2002

49. Thuma, J., Gilders, R., Verdum, M. and Louks, A. Circadian Rhythm of Cortisol Confounds Cortisol Responses to Exercise: Implications for Future Research. *J Appl Physiol* 78: 1657-1664, 1995

50. Van Bruggen, M., Hackney, A., McMurray, R. and Ondrak, K. The relationship between serum and salivary cortisol levels in response to different intensities of exercise. *Int J Sports Physiol Perform* 6: 396-407, 2011

51. Williams, A., Ismail, N., Sharma, A. and Jones, D. Effects of resistance exercise volume and nutritional supplementation on anabolic and catabolic hormones. *European Eur J Appl Physiol* 86: 315-321, 2002

Table 1. Strength testing data (mean ± SD) all exercises used

	5RM (kg)	Estimated 1RM (kg)
Back Squat	97.29 ± 19.47	112.08 ± 22.81
Chest press	77.29 ± 12.94	89.17 ± 14.75
Deadlift	110.42 ± 25.40	126.88 ± 29.33
Bent over row	68.54 ± 11.00	78.86 ± 13.29
Romanian deadlift	88.75 ± 11.51	101.82 ± 13.83

Table 2. Descriptive data (mean ± SD) for the four measures of training load and the Δ cortisol and Δ lactate following the three resistance training protocols (55%, 70%, 85% 1RM)

Protocol	VL (kg)	SRPE	RPEL	RPEL-2	Δ cortisol (µg/dl)	Δ lactate (mmol/L)
55% 1RM	12396 ± 944	8.0 ± 1.6	4596 ± 1145	347 ± 50	0.33 ± 0.39	5.7 ± 2.0
70% 1RM	10560 ± 1753	6.9 ± 1.4	3154 ± 589	279 ± 70	0.05 ± 0.19	4.8 ± 1.7
85% 1RM	8319 ± 1412	6.2 ± 2.2	2168 ± 715	248 ± 77	0.25 ± 0.19	5.1 ± 2.1

Table 3. Percentage difference with 90% CL and practical inferences, for between protocol comparisons (55%, 70%, 85% 1RM) on outcome measures.

	Intensities (% 1RM)	Mean % difference (±90%CL)	Practical Inference
VL	55% to 70%	17 ±63	Most likely a substantial difference
	55% to 85%	46 ±79	Most likely a substantial difference
	70% to 85%	24 ±7.5	Most likely a substantial difference
SRPE	55% to 70%	16 ±9.4	Very likely a substantial difference
	55% to 85%	29 ±12	Most likely a substantial difference
	70% to 85%	12 ±17	Likely a substantial difference
RPEL	55% to 70%	21 ±11	Very likely a substantial difference
	55% to 85%	36 ±12	Most likely a substantial difference
	70% to 85%	12 ±17	Likely a substantial difference
RPEL-2	55% to 70%	49 ±15	Most likely a substantial difference
	55% to 85%	107 ±14	Most likely a substantial difference
	70% to 85%	39 ±21	Very likely a substantial difference
Δ lactate (mmol/L)	55% to 70%	18 ±16	Likely a substantial difference
	55% to 85%	15 ±13	Likely a substantial difference
	70% to 85%	-3 ±17	Possibly a trivial difference
Δ cortisol (μg/dl)	55% to 70%	148 ±156	Very likely a substantial difference
	55% to 85%	102 ±184	Likely a substantial difference
	70% to 85%	-19 ±44	Possibly a substantial difference