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Heart Rate Determined Rest Intervals in Hypertrophy-Type Resistance Training

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ABSTRACT

Buskard A, Wood R, Mullin E, Bruneau M, Jaghab A, Thompson B. Heart Rate Determined Rest Intervals in Hypertrophy-Type Resistance Training. **JEPonline** 2017;20(1):13-22. The purpose of this study was to determine if between-set rest intervals in hypertrophy-type resistance training (HTRE) are more effective when standardized to an individual marker of recovery (heart rate; HR) than when standardized to a pre-determined unit of time (60 sec). Thirty-four recreationally trained college males (22.7 ± 3.5 yrs; 7.1 ± 4.2 yrs continuous RE experience ≥2 $d \cdot wk^{-1}$) performed otherwise-identical bench press protocols (60% 1RM, max sets of >8 repetitions to failure) differing only by method used to calculate between-set rest intervals. Subjects completed significantly more ($P<0.001$, Cohen's d = .76) repetitions under HR-determined rest conditions (55.1 ± 29.4 vs. 39.5 ± 16.6) and experienced 25.8% faster set-to-set performance decline under time-based rest conditions ($P<0.01$, Cohen's d = .50). We concluded individualized rest intervals may be more effective than traditional (time-based) methods when extrapolated over the course of a prudent multi-week training program. While our study is not the first to standardize between-set rest intervals in HTRE to a physiological marker of recovery such as HR, it does appear to be the first to standardize them to values recorded after the first working set in the current exercise session.

Key Words: Rest Interval, Strength Training, Heart Rate, Hypertrophy

INTRODUCTION

Strength training has many benefits for sport performance, not the least of which is increased muscle mass (2,18,19). To date, high volumes of intra-session resistance exercise (RE) performed at moderate intensity (60-75% one repetition maximum [1RM]) are believed to be among the most effective conditions for stimulating hypertrophy (2,9,22,34). In addition, short rest intervals are accepted as an important element of hypertrophy training with most researchers recommending rest intervals of 30 to 180 sec between sets as optimal (2,37,38).

However, these recommendations appear to be complicated by the fact that the optimal amount of rest between sets appears to be specific to an individual and his or her pre-exercise training status (4,26,36). This is one reason why generalized between-set rest recommendations in hypertrophy training may be problematic (5,37). The focus of our study was to determine whether between-set rest intervals in hypertrophy-type resistance training (hypertrophy training) are more effective when standardized to a physiological marker of recovery (heart rate) than when standardized to a pre-determined unit of time (60 sec).

Given the correlation between high training volumes and hypertrophy (4,18,36-39), loading schemes that facilitate higher within-session training volumes may lead to greater hypertrophy if continued over the course of an extended (multi-week) training program (39). The larger hypertrophic response is likely due to an increase in mechanical strain (8,26), metabolic stress (26,30,32), hormone release (12,13,33,36), and hormone-receptor interaction (19,31,32) in working muscle. An increase in motor-unit recruitment to include larger, more hypertrophy-prone fiber types has also been suggested as a contributing factor (11,13,19,26,31).

An individual's capacity to complete a high volume of RE within a given training session is inversely related to the average amount of rest taken between sets (5,7,16,27,37,39). This relationship is primarily due to the fact that shorter rest periods allow the body less time to clear function-reducing metabolites such as carbon dioxide and free hydrogen from muscle (5,30,36). Rationale for the development of individualized rest periods based on a real-time indicator of fatigue (HR) is such that this method would enable exercisers to adjust between-set rest intervals on a set-by-set basis, thereby preventing early cessation of exercise due to unmanageable levels of metabolic accumulation. By increasing the number of sets in which a target number of repetitions is completed, individuals may be able to increase their total training volume, which may in turn lead to greater hypertrophy if continued over the course of an appropriately-designed multi-week training program (4,37-39).

The short rest intervals characteristic of hypertrophy training tend to cause an acute build-up of glycolytic byproducts (5,7,17,20,21,30) known to have a beneficial effect on testosterone (25,36) and growth hormone (12,13,33) release while having a detrimental effect on muscle contractility (7,30,32,35,37). The strength of these effects is believed to diminish with time following completion of a set (30) as a result of ongoing metabolic clearance. Many metabolic byproducts, such as free hydrogen, are known to cause an increase in HR when they accumulate (16), thus providing a rationale for the use of HR as a physiological marker of recovery in the present study. Furthermore, 'optimal rest' can be thought to have occurred the moment sufficient contractile function is restored to the working muscle (38). In this manner, total intra-session training volume is not compromised and the maximum benefit from metabolic disruption on anabolic signaling can be realized.

To summarize, researchers recommend 30 to 90 sec rest intervals between sets of hypertrophy training because the moment of optimal rest typically occurs within this time frame (5,37). While these recommendations may not be ideal for all individuals (38), factors such as age (5), training status (28), energy system use (28), and the degree of contractile impairment (30,35) can influence the amount of recovery an individual needs to achieve optimal rest over the course of multiple sets.

The purpose of this study was to determine if differences exist in the number of bench press repetitions recreationally-trained college males can complete with a moderate load under a repeated-sets-to-failure task when between-set rest intervals are standardized to time (60 sec) compared to when between-set rest intervals are standardized to an indicator of recovery status (HR).

METHODS

Subjects

Thirty-four (22.7 ± 3.5 yrs) recreationally trained college males (7.1 ± 4.2 yrs continuous RE experience, ≥2 d·wk^{-1}) participated in this study. Exclusion criteria included musculoskeletal injuries to the elbow, shoulder, wrist, or any other area deemed to compromise subject health and/or ability to complete the study. An answer of "yes" for any item in the medical history questionnaire precluded participation. The Springfield College (MA, USA) institutional review board approved all procedures prior to subject recruitment and each subject completed an informed consent, health history questionnaire, and demographic statistics sheet prior to data collection. Subjects were tested in the afternoon on nonconsecutive days separated by no more than 7 days under a randomized cross-over design. Testing sessions differed only with respect to the method used to determine the length of between-set rest intervals. Subjects were advised to refrain from any chest-pressing exercise for 48 hrs prior to data collection and advised to avoid caffeine and pre-exercise supplements for at least 4 hrs prior to data collection.

Procedure

Submaximal 1RM was determined between 2 and 7 days prior to the first data collection session using the protocol outlined by Baechle and Earle (2). After 1RM determination, subjects performed two light sets (30% 1RM for 15 repetitions, 50% 1RM for 10 repetitions) to gain familiarity with the movement and testing cadence of '1 sec down, 1 sec up, 1 sec pause at top'.

Details of data collection are outlined in Figure 1. Subjects were instructed to complete as many repetitions as possible at the prescribed cadence. Failure was deemed to occur when the subject could no longer demonstrate proper technique, could not maintain an eccentric phase lasting ≥1 sec, or requested spotter assistance. Subjects were allowed to continue if they required more than 1 sec on the concentric phase, provided proper technique was evident. Data collection ceased when the subject failed to complete at least 8 repetitions.

Figure 1. Protocol Outline

	HR - Determined Rest	Time-Based Rest
Warm-up	1 x 10 @ 40% 1RM	
	rest 60 s	
	1 x 10 @ 40% 1RM	
	rest 60 s	
TESTING PROTOCOL		
Set 1	≥ 8 reps @ 60% 1RM	
	rest: wait until HR reaches rate recorded 45s after completion of the first working set	**rest:** 60 s
Set 2	≥ 8 reps @ 60% 1RM	
	rest: wait until HR reaches rate recorded 45s after completion of the first working set	**rest:** 60 s
Set 3	≥ 8 reps @ 60% 1RM	
	rest: wait until HR reaches rate recorded 45s after completion of the first working set	**rest:** 60 s
repeat until participant can no longer complete ≥ 8 repetitions		

Time-Based Rest

Under the time-based rest conditions, subjects rested 60 sec between sets. Rest intervals were monitored with a nearby tablet computer (iPad 2, Apple, Cupertino, CA.) and began as soon as the subject returned the barbell to the 'racked' position unassisted.

HR-Determined Rest

Subjects wore a commercially available HR monitor (Ekho E-10, Ekho, Dallas, TX) that was monitored by the lab assistant throughout the testing session. Forty-five seconds after completion of the first working set, each subject's HR was recorded. This rate was then subsequently referred to as the 'start rate', and was the benchmark from which all the subsequent rest intervals were determined (subjects began each subsequent set when their HR dropped back down to the start rate). Upon reaching a HR within 2 beats·min^{-1} of the start rate, the subjects were instructed to prepare for the next set by gripping the barbell. Once HR matched the start rate, the subject was instructed by the laboratory assistant to begin the next set. Immediately after each exercise set, the same tablet computer was used to monitor elapsed time between sets. Peak post-set heart rate, defined as the highest heart rate recorded during each rest interval, was recorded in addition to the number of repetitions completed for each set. The subject was blinded to his HR at all times during data collection.

Statistical Analysis

Data are presented as mean ± SD. A priori power analysis was conducted using G*Power software developed by Faul, Erdfelder, Buchner, and Lang (10). To obtain 80% power with a medium estimated effect size of .5, a subject pool of 34 subjects was needed. Each dependent variable was assessed with a repeated measures *t*-test and Cohen's d effect sizes using pooled standard deviation were calculated for differences in work output and rate of performance decline. Alpha levels were set at P<0.05 and the data were analyzed using IBM SPSS v.20.

RESULTS

Subjects performed significantly more (P<0.001, Cohen's d = .76) repetitions (55.1 ± 29.4 vs. 39.5 ± 16.6) under the HR-determined rest conditions and performed 20.5 ± 11.8% fewer repetitions relative to the previous set. Under the time-based rest conditions, subjects performed 27.6 ± 15.1% fewer repetitions relative to the previous set. This difference represented a 25.8% faster performance decline under the time-based rest conditions and was statistically significant (P<0.01) with a medium effect size (0.50).

DISCUSSION

The purpose of this investigation was two-fold: (a) to see if differences exist in the number of bench press repetitions recreationally trained college-aged men could complete under time-based versus HR-based rest conditions, and to see if differences exist in the rate of performance decline under the same conditions. The primary findings were that the subjects could complete nearly 40% more repetitions under individualized rest conditions and experienced 25% quicker set-to-set performance decline under time-based rest conditions. In light of the established dose-response relationship between training volume and hypertrophy (39) as well as the detrimental effects of insufficient rest on short-term muscle function (11,15,30), the results indicate between-set rest intervals in hypertrophy training may be more effective when standardized to HR than when standardized to time.

A third key finding is that the amount of between-set rest the subjects needed under HR-determined conditions steadily increased as the number of successfully completed sets increased (Figure 2). When permitted longer between-set rest intervals (a function of the body needing progressively-more time for recovery), the subjects were able to attain higher repetition totals and a slower rate of performance decline. Higher repetition totals and slower performance decline may help augment hypertrophic outcomes, as these factors contribute to an increased capacity for training volume within a given session (5,36,37). The finding that the subjects needed progressively-more rest between sets under HR-determined rest conditions also illustrates the possibility that predetermined rest intervals (60 sec in our case) do not correspond to a consistent physiological state, which is an important goal between sets of hypertrophy training (7). The increasing duration of rest the subjects needed between sets to repeatedly complete the target repetition number is in alignment with research by Abdessemed et al. (1) who demonstrated that lengthening recovery between sets allowed for the use of higher loads during a similar 5 wk program. The finding is in similar accord with research by Willardson and Burkett (39) who found that the total number of squat and bench press repetitions the experienced male lifters could complete increased directionally with longer rest periods.

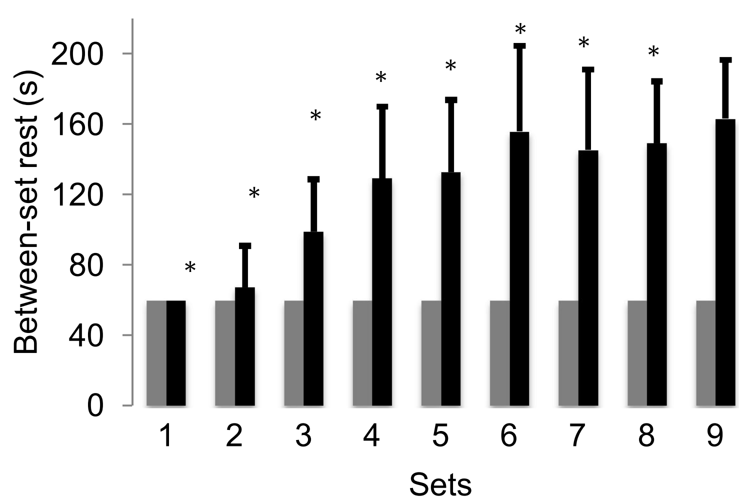

Figure 2. Bar Graph Showing Mean Rest Periods Duration Under Time (■) and HR-Based (■) Rest Conditions.

One expected outcome from this study is 60 sec rest was insufficient to ensure that the subjects could repeatedly complete or exceed the goal of 8 or more repetitions. We expected this to occur due to the large number of studies that reported a similar decline in bench press performance when a 60 sec rest interval was used (5). The finding that the subjects averaged less than 3 sets before failure under the time-based rest conditions versus slightly over 5 sets under the HR-determined conditions demonstrates this point (Figure 3). These results are concordant with what was previously reported by researchers (1,9,15,19,21,37) who used similar experimental designs and concluded that 60 sec rest intervals correlated with significant performance decline during hypertrophy-type resistance training. The finding that the subjects required an average increase of 10% more rest after each set relative to the previous set aligns with what has been reported by Billat (3), de Sousa et al. (6), and Hopker, Jobson, and Pandit, (14), and may be considered further evidence that time-based rest intervals may not be the most effective method for use in hypertrophy training.

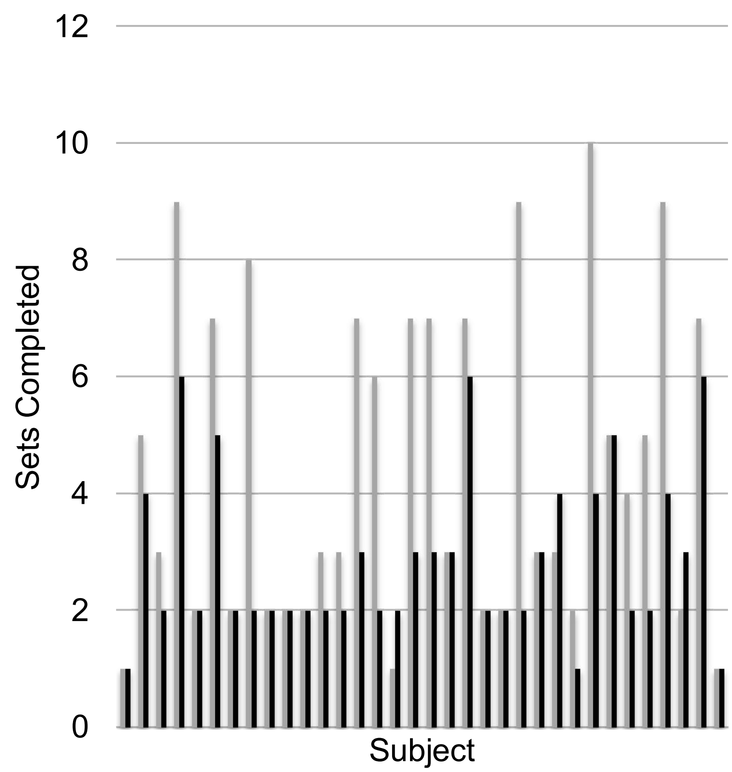

Figure 3. Within-Subjects Number of Sets Completed Under Time (■) and HR-Based (■) Rest Conditions.

Findings that contradict what was found in the present study with respect to the efficacy of HR-determined rest in hypertrophy training were reported by Larson and Potteiger (23). They found no significant differences between the 3-min timed rest, the 1:3 work rest ratio, and the time to reach 60% age-predicted HR (APMHR) on the number of back squat repetitions that 15 resistance trained men could complete with 85% 10-RM over the course of 3 sets to failure. The differential outcome between Larson and Potteiger's (23) study and the present study may be explained by the fact that a different exercise, load, and set configuration were used. The differential outcome may be further explained by the nature of how HR was used as a marker of recovery in the respective studies. Larson and Potteiger (23) used an external mechanism to determine start rate (% of the APMHR) while the present study standardized HR rest to an internal marker (HR recorded during a previous recovery state). To the best of our knowledge, the present study appears to be the first to investigate rest in hypertrophy training relative to a previous recovery state.

CONCLUSIONS

Our investigation sought to determine whether rest intervals in hypertrophy training are more effective when standardized to an individual marker of recovery (post-interval HR) than when standardized by time. Thirty-four recreationally trained college males completed significantly more bench press repetitions with a load characteristic of those recommended for use in hypertrophy training when between-set rest intervals were determined by HR than when between-set rest intervals were determined by time. Our findings are novel and provide evidence that rest intervals in hypertrophy training are more effective when standardized to an individual marker of fatigue/recovery than when standardized to a pre-determined unit of time. The benefit of higher training volumes on hypertrophy is rooted in the dose-response relationship shared between the two (4,18,29,36,38).

However, the primary purpose of our study can only be partially answered by the data collected because we did not investigate whether a significant reduction in circulating metabolites occurred as a result of the progressively longer rest intervals that took place under the HR-determined rest conditions. A significant reduction in metabolic stress may offset the benefits of a higher within-session training volume through a reduction in average metabolic stress experienced between sets as a result of increased metabolic clearance. Future research is necessary to determine the magnitude of the drop in metabolic stress concomitant with longer rest intervals as well as whether a drop in metabolic stress compromises the release of anabolic hormones before the HR-determined rest periods can be justifiably recommended for widespread use in hypertrophy training. Additionally, the extent to which a given heart rate represents a consistent 'recovery state' (with respect to markers of metabolic stress like pH, free phosphate, and catecholamine levels) across multiple sets has yet to be determined.

Aside from examining the influence of metabolic stress on anabolic hormone release, researchers should validate our use of the HR recorded 45 sec after completion of the working set as the benchmark from which all subsequent rest periods were determined. We chose the 45 sec HR as a benchmark due to the novelty of our study, and we based our decision to use this time frame from previously reported literature with aerobic exercise training. Still, despite our use of HR as an individual marker of recovery, future research efforts should explore other standardized markers of physiological recovery (e.g., blood pH, ventilation rate, rating of perceived exertion, etc.) that may modulate the volume of bench press repetitions performed during a sub-maximal resistance exercise session.

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REFERENCES

1. Abdessemed D, Duché P, Hautier C, Poumarat G, Bedu M. Effect of recovery duration on muscular power and blood lactate during the bench press exercise. ***Int J Sports Med.*** 1999;20:368-373.

2. Baechle TR, Earle RW. (Editors). ***Essentials of Strength Training and Conditioning***. Champlain, IL: Human Kinetics, 2008.

3. Billat V. Use of blood lactate measurements for prediction of exercise performance and control of sports training. ***Sports Med.*** 1996;22:157-175.

4. Crewther B, Keogh J, Cronin J, Cook C. Possible stimuli for strength and power adaptation: Acute hormonal responses. ***Sports Med.*** 2006;36:215-238.

5. De Salles BF, Simão R, Miranda F, Novaes JD, Lemos A, Willardson JM. Rest interval between sets in strength training. ***Sports Med.*** 2009;39:765-777.

6. De Sousa NM, Magosso RF, Pereira GB, Souza MV, Vieira A, Marine, DA, Baldissera V. Acute cardiorespiratory and metabolic responses during resistance exercise in the lactate threshold intensity. ***Int J Sports Med.*** 2012;33:108-113.

7. Denton J, Cronin J. Kinematic, kinetic, and blood lactate profiles of continuous and intraset rest loading schemes. ***J Strength Cond Res.*** 2006;20:528-534.

8. Ebbeling CB, Clarkson PM. Exercise-induced muscle damage and adaptation. ***Sports Med.*** 1989;7:207-234.

9. Faigenbaum AD, Ratamess NA, McFarland J, Kaczmarek J, Coraggio MJ, Kang J, Hoffman JR. Effect of rest interval length on bench press performance in boys, teens, and men. ***Pediatr Exerc Sci.*** 2008;20:457-469.

10. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3:1: Tests for correlation and regression analyses. ***Behav Res Methods.*** 2009;41: 1149-1160.

11. Gandevia SC. Spinal and supraspinal factors in human muscle fatigue. ***Physiol Rev.*** 2001;81:1725-1789.

12. Godfrey R, Madgwick Z, Whyte G. The exercise-induced growth hormone response in athletes. ***Sports Med.*** 2003;33:599-613.

13. Goto K, Ishii N, Takamatsu K. Growth hormone response to training regimen with combined high-and low-intensity resistance exercises. ***J Sport Health Sci.*** 2004;2: 111-118.

14. Hopker JG, Jobson SA, Pandit JJ. Controversies in the physiological basis of the “anaerobic threshold” and their implications for clinical cardiopulmonary exercise

testing. ***Anaesthesia.*** 2011;66:111-123.

15. Hunter SK, Duchateau J, Enoka RM. Muscle fatigue and the mechanisms of task failure. ***Exerc Sport Sci Rev.*** 2004;32:44-49.

16. Iglesias E, Boullosa DA, Dopico X, Carablleira E. Analysis of factors that influence the maximum number of repetitions in two upper-body resistance exercises: Curl biceps and bench press. ***J Strength Cond Res.*** 2010;24:1566-1572.

17. Kjaer M. Epinephrine and some other hormonal responses to exercise in man. ***Sports Med.*** 1989;10:2-15.

18. Komi P. (Editor). ***Strength and Power in Sport.*** (2nd Edition). Oxford, U.K.: Blackwell Publishing Company, 2003.

19. Kraemer WJ, Ratamess NA. Hormonal responses and adaptations to resistance exercise and training. ***Sports Med.*** 2005;5:339-361.

20. Kraemer WJ, Noble BJ, Clark MJ, Culver BW. Physiologic responses to heavy-resistance exercise with very short rest periods. ***Int J Sports Med.*** 1987;8:247-252.

21. Kraemer WJ. A series of studies- the physiological basis for strength training in American football: Fact over philosophy. ***J Strength Cond Res.*** 1997;11:131-142.

22. Kraemer WJ, Adams, K, Cafarelli, E, Dudley, G, Dooly, C, Feigenbaum, M, Triplett-McBride, T. Progression models in resistance training for healthy adults. ***Med Sci Sports Exerc.*** 2002;34:364-380.

23. Larson G, Potteiger J. A comparison of three different rest intervals between multiple squat bouts. ***J Strength Cond Res.*** 1997;11:115-118.

24. Lawton T, Cronin J, Drinkwater E, Lindsell R, Pyne D. The effect of continuous repetition training and intra-set rest training on bench press strength and power. ***J Sports Med Phys Fitness.*** 2004;44:361-367.

25. Lu SS, Lau CP, Tung YF, Huang SW, Chen YH, Shih HC, Tsai SC, Lu CC, Wang SW, Chen JJ, Chien EJ, Chien CH, Wang PS. Lactate and the effects of exercise on testosterone secretion: Evidence for the involvement of a cAMP-mediated mechanism. ***Med Sci Sports Exerc.*** 1997;29:1048-1054.

26. McDonagh MJ, Davies CT. Adaptive response of mammalian skeletal muscle to exercise with high loads. ***Eur J Appl Physiol Occup Phys.*** 1984;52:139-155.

27. Miranda H, Fleck SJ, Simão R, Barreto AC, Dantas EH, Novaes J. Effect of two different rest period lengths on the number of repetitions performed during resistance training. ***J Strength Cond Res.*** 2007;21:1032-1036.

28. Richmond S, Godard M. The effects of varied rest periods between sets to failure using the bench press in recreationally trained men. ***J Strength Cond Res.*** 2004;18: 846-849.

29. Robinson JM, Stone MH. Effects of different weight training exercise/rest intervals on strength, power, and high intensity exercise endurance. ***J Strength Cond Res.*** 1995;9:216-221.

30. Sahlin K, Ren JM. Relationship of contraction capacity to metabolic changes during recovery from a fatiguing contraction. ***Amer Phys Soc.*** 1989;67:648-654.

31. Sale DG. Influence of exercise and training on motor unit activation. ***Exerc Sport Sci Rev.*** 1987;15:95-151.

32. Smith RC, Rutherford OM. The role of metabolites in strength training. I. A comparison of eccentric and concentric contractions. ***Eur J Appl Physiol Occup Phys.*** 1995;71:332-336.

33. Stokes K. Growth hormone responses to sub-maximal and sprint exercise. ***Growth Hormone & IGF Research.*** 2003;13:225-238.

34. Stone MH, Fleck SJ, Triplett NT, Kraemer WJ. Health- and performance-related potential of resistance training. ***Sports Med.*** 1991;11:210-231.

35. Tesch P, Colliander E, Kaiser P. Muscle metabolism during intense, heavy-resistance exercise. ***Eur J Appl Physiol.*** 1986;4:362-366.

36. Villanueva M. Influence of rest interval length on acute testosterone and cortisol responses to volume-load-equated total body hypertrophic and strength protocols. ***J Strength Cond Res.*** 2012;26:2755-2764.

37. Willardson JM. A brief review: Factors affecting the length of the rest interval between resistance exercise sets. ***J Strength Cond Res.*** 2006;20:978-984.

38. Willardson JM, Burkett LN. The effect of different rest intervals between sets on volume components and strength gains. ***J Strength Cond Res.*** 2008;22:146-152.

39. Willardson JM, Burkett LN. A comparison of 3 different rest intervals on the exercise volume completed during a workout. ***J Strength Cond Res.*** 2005;19:23-26.