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Effects of a Resistance Exercise Session on the Physiological Response and Time to Exhaustion during Submaximal and Maximal Cycling

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ABSTRACT

Garay LC, Rhea M, Reis VM, Simão R, Menezes P, Strom-Olsen H, Novaes J. Effects of a Resistance Exercise Session on the Physiological Response and Time to Exhaustion during Submaximal and Maximal Cycling. **JEPonline** 2013;16(1):36-44. The purpose of this study was to investigate the effects of a resistance exercise session on the physiological response and time to exhaustion during submaximal and maximal cycling. Ten men (22.5 ± 3.1 yrs; 72.5 ± 10.9 kg; 174 ± 5.2 cm; 23.8 ± 2.5 kg·m^{-2}) with a mean VO_2 max of 44.2 ± 6.9 mL·kg^{-1}·min^{1} volunteered to participate in this study. Each subject underwent 4 testing sessions: (1) maximum aerobic capacity test; (2) 10 RM test; (3) submaximal and maximal cycling trials; and (4) both resistance exercise and submaximal and maximal cycling trials. Paired *t* test indicated a significant effect of resistance exercise on cycling performance and a significant decrease of 17.5% in time to exhaustion (P<0.001). The results indicate that when resistance exercise is performed immediately before submaximal or maximal cycling, the cycling performance is impaired and the physical stress is much larger.

Key Words: Concurrent Training, Endurance Training, Time Limit

INTRODUCTION

The effects of strength training (ST) and aerobic training (AT) are well documented in the literature (15,17-19,21). However, studies have shown varying results when ST and AT are combined in a single session, called concurrent training (CT). Significant improvements in endurance performance (11) and in strength and power (16,20,23) have been found in CT, specifically when ST is performed immediately before AT. However, decreases in cycle time performance (23) and in strength and power development due to muscle fatigue (9,12,13) have also been found. Performing ST before aerobic exercise at submaximal intensities may also increase rate of perceived exertion (RPE) compared to performing aerobic exercise first (14).

To date, few studies have investigated effects of a resistance exercise (RE) on submaximal aerobic exercise (AE) (3,10). Crawford and colleagues (1991) examined this relationship and found negative physiological responses in cycling at submaximal intensities (60 to 73% of VO_2 max). These were demonstrated by a significant increase in blood lactate levels and heart rate (HR) within the first 5 min of cycling when preceded by RE compared to no prior exercise. However, there is a low correlation between the number of muscle groups used (10) and rest intervals (3) in ST and AT.

As yet, little is known about the acute interference of RE on physiological responses and time to exhaustion in maximal effort cycling. Therefore, the purpose of this study was to investigate the effects of a resistance exercise session on the physiological response and time to exhaustion during submaximal and maximal cycling.

METHODS

Subjects

Ten young (22.5 ± 3.1 yrs; 72.5 ± 10.9 kg; 174 ± 5.2 cm; 23.8 ± 2.5 $kg{\cdot}m^{-2}$; 182.5 ± 11.6 $beats{\cdot}min^{-1}$ HR max; 44.2 ± 6.8 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$) healthy males volunteered to participate in the study. All subjects exercised habitually, with at least 1 yr experience in both strength training (leg press, leg curl, and standing calf raise on the leg press; at least 2 $times{\cdot}wk^{-1}$) and aerobic training (indoor cycling at least 3 $times{\cdot}wk^{-1}$ at 65-90% HR max).

The subjects were informed about the procedures, risks, and benefits of the present study. All subjects completed a Physical Activity Readiness Questionnaire, and they signed an informed consent before participation, which thoroughly explained the training and testing procedures. The study was conducted according to the Declaration of Helsinki.

The subjects were instructed not to change their daily routines, not to exercise within 3 hrs after a meal, and to have an interval of a 1 wk between each testing session. All subjects reported to the laboratory in the afternoon. The volunteers participated in four visits to the gym.

Procedures

Maximum Aerobic Capacity Test (Visit I)

To determine the maximum aerobic capacity (VO_2 max), the Modified Balke's Maximum Scaled Protocol (5) for a bicycle ergometer with a mechanical braking system (Monark Test Ergometer, Ergomedic 828E) was used. The subjects were instructed to remain seated and to maintain a cycling frequency of 60 $rev{\cdot}min^{-1}$. The test protocol consisted of a progressive increase in workload, with an initial load of 25 W. Twenty-five watt increments were added every 2 min until voluntary maximum exhaustion or until the participant was unable to maintain the frequency of 60 $rev{\cdot}min^{-1}$. Power was determined from the highest load reached during the test and was calculated according to the following equation (2).

VO_2 max = [(maximal load x 6 x 60) x 1, 8] ÷ corporal mass + 7 (maximal load and corporal mass)
VO_2 max= $mL \cdot kg^{-1} \cdot min^{-1}$
Maximal load = Kp
Corporal mass = Kg

10 RM Test (Visit II)

The 10 RM resistance for the leg-press, the seated leg curl, and the standing calf raise on the leg press was determined for all subjects 72 hrs after the maximal cycling test (Visit I), and the tests were conducted in the following order: leg-press, seated leg curl, and standing calf raise on the leg press. All machine exercises were performed on the Technogym, Selection Line (Gambetolla, Cesena/Italy). To minimize error in the 10 RM tests, the following precautions were taken: (a) all subjects received standard instructions on the testing procedures and on exercise performance technique before testing; (b) subjects' exercise technique was monitored and corrected as needed during each test; and (c) all subjects received verbal encouragement during testing. Each subject had a maximum of 5 attempts at each exercise with 2- to 5-min rest intervals between attempts. After the 10 RM load was determined for a specific exercise, an interval no shorter than 10 min was allowed before the next exercise. Standard exercise technique was followed for each exercise, and no pause was allowed between the eccentric and the concentric phases of a repetition or between repetitions**.** For a repetition to be successful, a complete range of motion, as is normally defined for the exercise, had to be completed.

Submaximal and Maximal Cycling – AE (Visit III)

In order to evaluate the physiologic parameters and time to exhaustion, subjects started the cycle ergometer with a constant rotation of 60 $rev \cdot min^{-1}$ at the submaximal intensity of 50% VO_2 max for 6 min. Then, the intensity was adjusted to 100% VO_2 max until exhaustion or until the subject could no longer maintain 60 $rev \cdot min^{-1}$. The power (i.e., load) for each subject was obtained through the maximum capacity test, as explained in Visit I.

The maximal cycling time (i.e., time to exhaustion, Tlim) was determined and expressed in seconds. Blood lactate [La] concentrations were collected during both submaximal and maximal intensity (50-100% VO_2 max) periods using capillary blood from a fingertip. The Accutrend lactate analyzer (Boehringer Mannheim, Mannheim, Germany) was used, as it has recently been shown to have good accuracy and high reliability and linearity (4). Heart rate was measured immediately after 6 min. (50% VO_2 max) and at exhaustion (100% VO_2 max) or when the subject could no longer maintain 60 $rev \cdot min^{-1}$ using a Polar Heart Rate Monitor Model RS300X (Polar, Kempele, Finland). Rating of perceived exertion (RPE) was assessed at 50% and 100% of VO_2 max using Borg's table (6), from which each subject indicated his level of exertion at that very moment. Verbal encouragement was given by the evaluator for motivational purposes when the individuals found it hard to maintain the rotation frequency of 60 $rev \cdot min^{-1}$.

Resistance Exercise Proceeding Submaximal and Maximal Cycling (RE + AE) (Visit IV)

The subjects first completed a RE session, which consisted of one set of 10 repetitions on the leg-press, the seated leg curl, and the standing calf raise on the leg press. A single set per exercise was selected as it meets the minimum recommendation of ST to develop muscular fitness (=2 sets) (1) particularly when the same muscle group is used in concurrent training activities. The heaviest load attained in the 10 RM test (Visit II) was used, with a 5-min interval between each set. Subjects were instructed to remain seated for 10 min after RE, where they were prepared and positioned to begin the cycling session at submaximal and maximal intensities – AE, as described in visit III. Water was the only liquid the subjects were permitted to consume during all procedures, and the temperature was controlled at 19 - 20° C for both training sessions.

Statistical Analyses

Mean and standard deviation [Mean ± SD] were calculated. The paired *t* test was used and P<0.05 was set as the criterion for significant differences for the AE only and RE + AE conditions at both intensity levels (50% and 100% VO_2 max) for the following variables: Tlim, [La], total power in watts (TP/W), and HR. The Wilcoxon test was used for RPE. All analyses were obtained using the software Prism 5 for Windows (Version 5.03).

RESULTS

Blood Lactate Concentrations

Our results showed that RE + AE significantly increased blood lactate concentrations at both 50% (3.5 ± 0.7 vs. 4.8 ± 1.2 $mmol \cdot L^{-1}$, P=0.024) and 100% (9.9 ± 1.7 vs. 11.6 ± 1.5 $mmol \cdot L^{-1}$, P=0.003) cycling intensities when compared to AE alone (Figure 1).

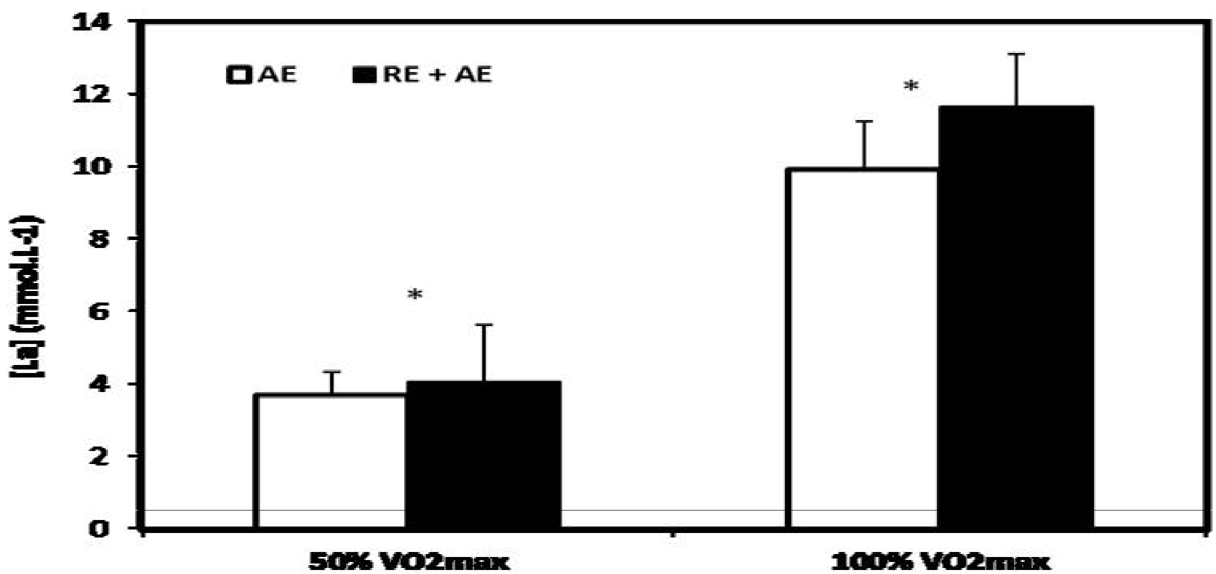

Figure 1. Blood lactate values [La] in aerobic exercise only (AE) and resistance exercise with aerobic exercise (RE + AE) at 50% and 100% VO_2 max of the total load achieved at maximal cycling test.
*Significant difference for P<0.05.

A significant reduction of 17.5% was found in time (sec) to exhaustion in the RE + AE (161.90 ± 44.28 sec) session compared to AE (196.30 ± 46.5 sec) (P<0.001) (Figure 2). Differences were found in rate of perceived exertion in RE + $AE_{50\%}$ (3.0 ± 1.1 vs. 3.8 ± 1.3, P=0.047), but not at RE + $AE_{100\%}$ (11.1 ± 0.6 vs.11.4 ± 0.5) when compared with AE. Age did not significantly influence (P>0.05) total load or time to exhaustion. Additionally, the correlation between VO_2 max and total load and time to exhaustion was not statistically significant. However, a significant correlation between the total load achieved and time to exhaustion was found in AE (200 ± 28.87 W) (P=0.0012) and RE + AE (200 ± 28.87 W) (P=0.0084).

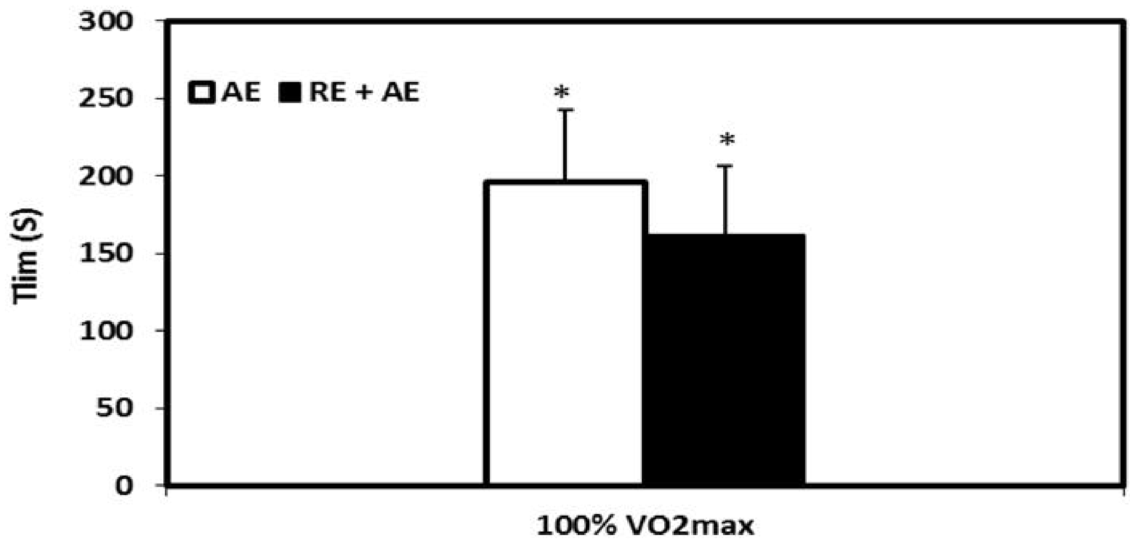

Figure 2. Exhaustion time (Tlim) in seconds (sec) for the aerobic exercise only (AE) and resistance exercise with aerobic exercise (RE + AE) at 100% VO_2 max of total load achieved at maximal cycling test. *Significant difference for P<0.05.

Heart Rate Response

A significant increase in heart rate was found in RE + $AE_{50\%}$ (137.6 ± 13.0 beats·min^{-1}) (P=0.02) compared to $AE_{50\%}$ (129.2 ± 12.2 beats·min^{-1}). However, despite a 3.1% increase in HR in RE + $AE_{100\%}$ (182.5 ± 11.6 beats·min^{-1}), no significant difference was found when compared with $AE_{100\%}$ (176.6 ± 10.0 beats·min^{-1}) (Figure 3).

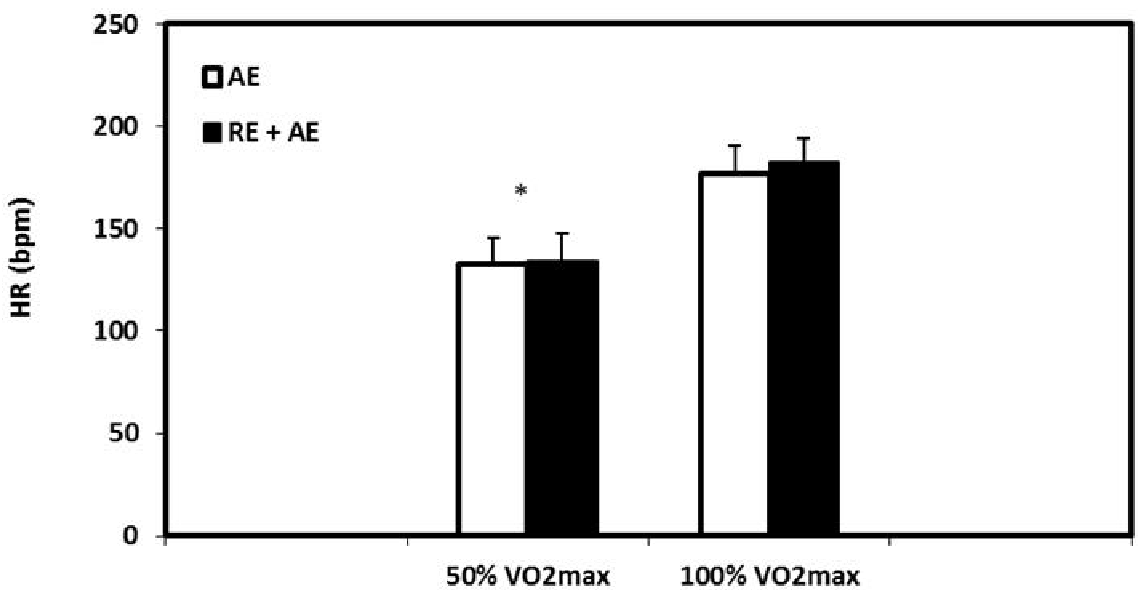

Figure 3. Heart rate (HR) in aerobic exercise only (AE) and resistance exercise with aerobic exercise (RE + AE) at 50% VO_2 max (P=0.02) and 100% VO_2 max (P>0.05). *Significant difference for P<0.05.

DISCUSSION

This study demonstrated a significant increase in blood lactate concentration at both intensities (50% and 100% of VO_2 max) in RE + AE, which showed an interference of RE on maximal and submaximal aerobic performance (Figure 1). Some authors (10) also reported a significant increase of [La] in the first 5 min of exercise at 63-73% VO_2 max in CT (3.4 ± 1.3 mmol·L^{-1}; 4.1 ± 1.7 mmol·L^{-1}) compared to AE alone (2.0 ± 1.5 mmol·L^{-1}, 2.0 ± 0.8 mmol·L^{-1}). An interesting finding in the present study was that individuals with greater loads (Kg) in the 10 RM leg press (260 ± 66.8), the seated leg curl (79 ± 13.7), and the standing calf raise on the leg press (288 ± 73.3) tolerated an increased time to exhaustion and produced less blood lactate in both AE and RE + AE. Inversely, subjects who tolerated lower loads had a shorter time to exhaustion and a higher production of [La].

While habitual RE may positively influence AE performance, it seems that RE immediately before AE can directly affect the subjects' ability to tolerate high workloads. The increased muscular demand of CT led to greater glycogen depletion and greater production of blood lactate, which is identified as a limiting factor for the capacity to tolerate high exertion intensities in CT (22,26-28).

Our study showed significant differences in RPE for RE + $AE_{50\%}$ (3.0 ± 1.1 vs. 3.8 ± 1.3, P=0.047), but not at RE + $AE_{100\%}$ (11.1 ± 0.6 vs. 11.4 ± 0.5). Bailey, Khodiguian, and Farrar (3) investigated AE performance (20 min; 60% VO_2 max; 60 rev·min^{-1}) after a RE session (9 exercises; 3 sets; 8-12 RM). They observed significant increases in RPE (5.8% vs. 7.2%) and double product (15.0% vs. 13.0%), demonstrating an interference from RE.

A significant increase in HR at RE + $AE_{50\%}$ (137.6 ± 13.0 beats·min^{-1}, P=0.02) was observed compared to $AE_{50\%}$ alone (129.2 ± 12.2 beats·min^{-1}) in our study. In spite of a 3.1% increase in HR in RE + $AE_{100\%}$ (182.5 ± 11.6 beats·min^{-1}), this finding was not significantly different from with $AE_{100\%}$ (176.6 ± 10.0 beats·min^{-1}). Supporting our findings, Bailey and colleagues (3) also found an increase in HR at 60% VO_2 max after 10 min (10.8%, P<0.0011) and 20 min (10.5%, P<0.001) of cycling in CT.

Chtara et al. (8) examined the effects of strategic order of administration (aerobic vs. strength; strength vs. aerobic, and strength and aerobic trained in isolation) in 12 wks of training. The aerobic-followed-by-strength group showed significantly greater improvement in VO_2 max (27.5%), respiratory compensation threshold (34.9%), maximum speed (V_{VO2} max) (27.1%), and time to exhaustion (Tlim) (29%) compared to the reverse condition. It is worth noting that the group that performed the RE in isolation also showed improvements in Tlim (16.3%). However, Marcinik et al. (24) showed an increase of 33.5% in Tlim on the cycle ergometer at 75% VO_2 peak measured before and after 12 wks of strength training in untrained individuals. Together, these results indicate isolated benefits of strength in aerobic performance.

For decades, the literature has shown that strength training increases muscle fiber size, anaerobic power, and muscular strength while aerobic training promotes changes in blood capillaries and in mitochondria, which improve aerobic performance (references). However, gaps still exist regarding the mechanisms responsible for the improvement of aerobic performance provided by a preceding bout of strength training. It has recently been shown that performing RE and AE in the same session does not influence maximal aerobic power adaptations, but demonstrated significant results on muscle quality enhancements in elderly healthy men (7). Miura et al. (25) asserted that heavy exercise prior to ergometer cycling may improve critical power and time through a reduction of [La] compared to exercise performed without prior heavy exercise. The authors reported that a preceding ST bout improved performance mainly through an enhanced aerobic component of exercise energetics. Another study (20) reported on the effects of a weight training program for the leg extensors with isokinetic cycling training (80 rev·min^{-1}) on maximal power output and endurance performance. The authors found that, at low cadences, P(max) improved in both training groups. However, pedaling technique compromised improvement of P(max) at high cadences.

CONCLUSIONS

This study indicates that when resistance exercise is performed immediately before a maximal or submaximal cycling (i.e., under concurrent training conditions) the performance is impaired and the physical stress is much larger. Hence, when the aerobic ability development is targeted, it might be prudent to either prescribe strength training after aerobic cycling or perform it on alternate days. Indeed, strength training proves to be important for the tolerance of high aerobic workloads in physically active subjects and should, therefore, be included in complex training programs. Exercise professionals should take adequate time during a program design to consider the implications of performing endurance training and resistance exercise in the same session or on the same day.

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REFERENCES

1. American College of Sports Medicine. Position stand on progression models in resistance training for healthy adults. ***Med Sci Sports Exerc.*** 2009;41:687-708.

2. ACSM. ***ACSM´s Guidelines for Exercise Testing and Prescription.*** Philadelphia, PA: Lippincott, Williams & Wilkins, 2007.

3. Bailey L, Khodiguian N, Farrar A. Effects of resistence exercices on selected physiological parameters during subsequent aerobic exercice. ***J Strength Cond Res.*** 1996;10:101-104.

4. Baldari C, Videira M, Madeira F, Sergio J, Guidetti L. Blood lactate removal during recovery at various intensities below the individual anaerobic threshold in triathletes. ***J Sports Med Phys Fitness.*** 2005;45:460-466.

5. Balke B, Ware RW. An experimental study of physical fitness of Air Force personnel. ***U S Armed Forces Med J.*** 1959;10:675-688.

6. Borg G. ***Borg's Perceived Exertion and Pain Scales.*** Champaing, IL: Human Kinetics, 1998.

7. Cadore EL, Izquierdo M, Alberton CL, Pinto RS, Conceicao M, Cunha G, Radaelli R, Bottaro M, Trindade GT, Kruel LF. Strength prior to endurance intra-session exercise sequence optimizes neuromuscular and cardiovascular gains in elderly men. ***Experi Geront.*** 2012; 47:164-169.

8. Chtara M, Chamari K, Chaouachi M, Chaouachi A, Koubaa D, Feki Y, Millet GP, Amri M. Effects of intra-session concurrent endurance and strength training sequence on aerobic performance and capacity. ***Brit J Sports Med.*** 2005;39:555-560.

9. Chtara M, Chaouachi A, Levin GT, Chaouachi M, Chamari K, Amri M, Laursen PB. Effect of concurrent endurance and circuit resistance training sequence on muscular strength and power development. ***J Strength Cond Res.*** 2008;22:1037-1045.

10. Crawford WW, Loy SF, Nelson AG, Conlee RK, Fisher AG, Allsen PE. Effects of prior strength exercise on the heart rate oxygen uptake relationship during submaximal exercise. ***J Sports Med Phys Fitness.*** 1991;31:505-509.

11. Davis WJ, Wood DT, Andrews RG, Elkind LM, Davis WB. Concurrent training enhances athletes' strength, muscle endurance, and other measures. ***J Strength Cond Res.*** 2008; 22:1487-1502.

12. de Salles BF, Simao R, Miranda F, Novaes Jda S, Lemos A, Willardson JM. Rest interval between sets in strength training. ***Sports Med***. 2009;39:765-777.

13. de Souza EO, Tricoli V, Franchini E, Paulo AC, Regazzini M, Ugrinowitsch C. Acute effect of two aerobic exercise modes on maximum strength and strength endurance. ***J Strength Cond Res.*** 2007;21:1286-1290.

14. Drummond MJ, Vehrs PR, Schaalje GB, and Parcell AC. Aerobic and resistance exercise sequence affects excess postexercise oxygen consumption. ***J Strength Cond Res.*** 2005; 19:332-337.

15. Everett MD, Kinser AM, Ramsey MW. Physical fitness and performance. Training for old age: Production functions for the aerobic exercise inputs. ***Med Sci Sports Exerc.*** 2007;39:2226-2233.

16. Glaister M, Stone MH, Stewart AM, Hughes M, Moir GL. The reliability and validity of fatigue measures during short-duration maximal-intensity intermittent cycling. ***J Strength Cond Res.*** 2004;18:459-462.

17. Hautala AJ, Kiviniemi AM, Makikallio TH, Kinnunen H, Nissila S, Huikuri HV, Tulppo MP. Individual differences in the responses to endurance and resistance training. ***Eur J Appl Physiol***. 2006;96:535-542.

18. Holviala J, Kraemer WJ, Sillanpaa E, Karppinen H, Avela J, Kauhanen A, Hakkinen A, Hakkinen K. Effects of strength, endurance and combined training on muscle strength, walking speed and dynamic balance in aging men. ***Eur J Appl Physiol.*** 2012;112:1335-1347.

19. Knuttgen HG. Strength training and aerobic exercise: Comparison and contrast. ***J Strength Cond Res.*** 2007;21:973-978.

20. Koninckx E, Van Leemputte M, Hespel P. Effect of isokinetic cycling versus weight training on maximal power output and endurance performance in cycling. ***Eur J Appl Physiol.*** 2010;109: 699-708.

21. Kraemer WJ. Muscle and strength: An evolution of study. ***Med Sci Sports Exerc.*** 2003;35: 1633.

22. Leveritt M, Abernethy PJ, Barry BK, Logan PA. Concurrent strength and endurance training. A review. ***Sports Med.*** 1999;28:413-427.

23. Levin GT, McGuigan MR, Laursen PB. Effect of concurrent resistance and endurance training on physiologic and performance parameters of well-trained endurance cyclists. ***J Strength Cond Res.*** 2009;23:2280-2286.

24. Marcinik EJ, Potts J, Schlabach G, Will S, Dawson P, Hurley BF. Effects of strength training on lactate threshold and endurance performance. ***Med Sci Sports Exerc.*** *1991;*23:739-743.

25. Miura A, Shiragiku C, Hirotoshi Y, Kitano A, Endo MY, Barstow TJ, Morton RH, Fukuba Y. The effect of prior heavy exercise on the parameters of the power-duration curve for cycle ergometry. ***Appl Physiol Nutrit Metabol.*** 2009;34:1001-1007.

26. Nelson AG, Arnall DA, Loy SF, Silvester LJ, Conlee RK. Consequences of combining strength and endurance training regimens. ***Phys Ther.*** 1990;70:287-294.

27. Sahlin K, Sorensen JB, Gladden LB, Rossiter HB, Pedersen PK. Prior heavy exercise eliminates VO_2 slow component and reduces efficiency during submaximal exercise in humans. ***J Physiol***. 2005;564:765-773.

28. Tomas A, Ross EZ, Martin JC. Fatigue during maximal sprint cycling: Unique role of cumulative contraction cycles. ***Med Sci Sports Exerc.*** 2010;42:1364-1369.