

Resistance exercise-induced microinjuries do not depend on 1 or 3 minutes rest time interval between series.

Las microlesiones inducidas por el entrenamiento con cargas no dependen de los intervalos de descanso entre series de 1 o 3 minutos.

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Abstract

In order to examine the effects of different rest intervals between sets on the muscle fiber integrity, 14 male subjects volunteered to participate in randomized crossover design methodology. All subjects completed 2 experimental training sessions. Both sessions consisted of 3 sets of 10 repetitions with 10 repetition maximum resistance bench press, cable pulldowns, military press, biceps curl, triceps curl, leg press, leg extension, and lying leg curls. The 2 experimental sessions differed only in the length of the rest period between sets and exercises: 1 session with a 1-minute and the other with a 3-minute rest period. The mechanical stress caused by the proposed training session cause similar damage in the muscle fibers do not depend of the 1 or 3 minutes of rest interval between series.

Key words: microinjuries; resistance exercise; creatine kinase.

Resumen

El propósito de ese estudio fue comparar los efectos de 2 diferentes períodos de descanso durante una sesión de entrenamiento con cargas en la integridad de la fibra muscular. Participaron de forma voluntaria 14 hombres en un estudio con diseño cruzado aleatorio. Todos los sujetos realizaron 2 sesiones de entrenamiento con cargas. Durante cada sesión, los sujetos completaban 3 series de 10 repeticiones máximas de press de banca, jalón en polea alta para dorsal, press militar, curl de bíceps con barra, extensión de tríceps trasnuca con mancuerna, prensa de piernas en máquina, extensión de rodillas en máquina, y flexión de rodillas en máquina. Las 2 sesiones experimentales diferían sólo en la longitud del período de descanso entre las series y los ejercicios: una sesión con 1 minuto y la otra con 3 minutos en los períodos de descanso. La tensión mecánica causada por las sesiones puede causar daños similares en las fibras musculares y no dependen de hacer 1 o 3 minutos de intervalo de descanso entre las series.

Palabras claves: microlesiones; ejercicios de resistencia; creatina kinasa.

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Introduction

Resistance training can increase strength, hypertrophy, muscular power, muscular endurance, and healthy status. The training program can be manipulated to meet training goals and address individual goals. The weight lifting involves the organization of exercises based on the resistance (load) used, the number of times the weight is lifted (repetitions), the number of times a given repetition number is completed (sets), the recovery between sets (rest interval) and the summation of the total number of repetitions performed during a training session, multiplied by the resistance used (volume) (Feigenbaum and Pollock, 1999; Pearson et al., 2000; Pollock, 1998; Kraemer and Ratamess, 2004; Simão et al., 2005). Mistakes in any of these variables in the progression of a program could, in theory, result in an overtraining syndrome (Rahimi et al., 2007; Hackney and Battaglini, 2007).

The length of a rest period has a critical role in designing strength-training session, however, this training variable is frequently ignored despite its significant effect on the metabolic, hormonal, and cardiovascular response to resistance training (Kraemer and Ratamess, 2004; Mavrommatakis et al., 2006). Previous studies examining rest periods of 0,5-5 minutes during a training session and between sets of isolated exercises (Kraemer et al., 1987; Larson and Potteiger, 1997; Matuszak et al., 2003; Richmond and Godard, 2004; Simão et al., 2005; Bottaro et al., 2005; Rahimi, 2005; Miranda et al., 2007; Rahimi et al., 2007) have shown that the rest period between sets and exercises has a significant effect on the total training volume, decrease in maximal voluntary contraction, exercise torque and fatigue perception. Decreased training volume in isolated exercises and in a training session with short rest periods between sets and exercises might in part be the result of physical and/or metabolic stress.

Resistance exercise with short rest intervals (1 min or less) leads to greater increases in circulating catecholamines, cortisol, and growth hormone than exercise bouts with longer rest intervals. Norepinephrine, epinephrine, cortisol, and growth hormone have all been implicated as causative agents behind the immunological changes that occur as a result of heavy resistance exercise sessions. Also Prostaglandin E2 (PGE2), Tumour Necrosis Factor- α (TNF- α), Interleukin 1b (IL-1b), Interleukin 6 (IL-6), and Interferon- α (INF α) increase after exercise bout (Mayhew et al., 2005; Tidball 2005; Bassit et al., 2007).

The serum level of skeletal muscle enzymes is a marker of the status of muscle tissue and varies widely in both pathological and physiological conditions. An increase in these enzymes may represent an index of cellular necrosis and tissue damage following acute and chronic muscle injuries. Changes in serum levels of muscular enzymes are also found in normal subjects and in athletes after strenuous exercise: the amount of enzyme from muscle tissue to blood can be influenced by physical exercise. This may be a consequence of both metabolic and mechanical causes. Indeed, metabolically exhausted muscle fibres exhibit a decrease in the membrane resistance following an increase in the internal free calcium ions, which promotes the activation of the potassium channel and proteolytic enzymes (calpains, caspases, etc). Another mechanism could be the local tissue damage with sarcolemma disruption and sarcomeric degeneration from Z-disk fragmentation (Mougios, 2007; Brancaccio et al., 2007).

Creatine kinase (CK), lactate dehydrogenase (LDH) and myoglobin have been extensively used as markers for muscle micro-injuries (Stupka et al., 2000; Chen and Hsieh, 2001; Clarkson and Hubal, 2002; Nosaka et al., 2002; ; Phillips et al., 2003; Tidball 2005; Bassit et al., 2007). Under such conditions CK serum concentration displays a greater increase than the serum concentration of other muscle proteins. As a result CK is used widely as such a marker of the status of muscle tissue (Clarkson and Hubal, 2002; Nosaka et al., 2002; Mougios, 2007; Brancaccio et al., 2007; Antunes Neto et al., 2007).

Few studies have been conducted to verify the differences between the exercise-induced microinjuries by according to the rest intervals between series. Mayhew et al (2005) make a study with nine college men (10 sets of 10 repetitions at 65% 1RM in leg press) and measured significant elevations from baseline CK concentration at 24H for 1 and 3 min rest intervals, as would be expected. However the results of the treatments were not equal, they noted that a significantly higher creatine kinase elevation following the 1-minute rest interval than following the 3-minute rest interval.

Thus the aim of this study was to verify if the same sequence of exercises performed in the same intensity, but with different intervals of rest affects the integrity of muscle fiber.

Material and method

Fourteen healthy adult males with resistance training experience volunteered to participate in this study. All volunteers were in good health (no medical history of health problems and were not using ergogenic substances or any other drugs) and free from muscle, cardiovascular or joint problems. The experiment was performed from 5 p.m. to 9 p.m. and the subjects were asked to refrain from eating and drinking and to keep themselves in a state of rest for at least two hours before the experiment started. The purpose, content, and procedures of the experiment were explained to the subjects in detail and their consent to be subjects in this experiment was obtained according to the Declaration of Helsinki and in accordance with the norms of the Brazilian National Health Council, under Resolution No. 196, promulgated on 10 October 1996, referring to scientific research on human subjects. All subjects performed weight training with a mean frequency of 3 sessions per week for approximately 2 hour per session and, predominantly, related 1-2 minute rest periods between sets and exercises.

To investigate the effect of 2 different rest periods between sets and exercises on plasma CK activity after a resistance training session, data were assessed on 3 nonconsecutive days in 3-4 total weeks. The anthropometrical data and 10 repetition maximums (10RM) of all subjects for all exercises performed were determined on the first day. Subjects performed the 2 exercise sessions separated by 2-3 weeks in a randomized crossover design methodology.

The 2 sessions comprised the same exercises performed in the same order, but with different rest periods between sets and exercises. Rest interval session 1 (1min) and rest interval session 3 (3min) were exactly the same, except 1- and 3-minute intervals were allowed between sets and exercises. The exercise sequence for both sessions was bench press, cable pulldowns, military

press, biceps curl, triceps curl, leg press, leg extension, and lying leg curls. The performance of 1min and 3min was separated by 2-3 weeks. All exercises in both sequences were performed for 3 sets with 10 repetitions with the predetermined 10RM of each subject for each exercise. Due to the exercise equipment design variations, we choose to describe the exercise force as arbitrary units (AU). This procedure was utilized in an attempt to simply matters for research purposes.

The mass of all weight plates and bars was determined with a precision scale and was used to calculate the 10RM of each exercise. The 10RM tests were assessed in the same sequence describes above. To minimize possible errors in the 10RM tests, the following strategies were adopted: (a) all subjects received standard instructions on the general routine of data assessment and the exercise technique of each exercise before testing, (b) the exercise technique of subjects during all testing sessions was monitored and corrected as needed, and (c) all subjects received verbal encouragement during testing.

One week after the 10RM test for each exercise, subjects performed 1min or 3min in a randomized crossover design. Two or three weeks after performing the first sequence, the second sequence was performed. Warm-up before each exercise sequence consisted of a 10 min in cycleergometer and articular mobilization for all involved joints. Immediately after warm-up the sequence of exercises was executed.

Subjects provided blood samples in a seated position from an antecubital vein into plain evacuated tubes in the morning after an overnight fast and sleep (day 0), 24, 48, and 72 hours after exercise sequence. The blood was left to coagulate at room temperature for 30 minutes and was centrifuged at 1500 g for 10 minutes to separate the serum, which was analysed immediately. CK was assayed spectrophotometrically through the use of commercially available kits that employed optimised conditions in accordance with the recommendations of the International Federation of Clinical Chemistry (Mougios, 2007).

One-way analysis of variance (ANOVA) with repeated measures was used to test differences between rest intervals and repetitions per set. The alpha level was set at 0.05 in order for a difference to be considered significant. When a significant effect was detected, a pairwise comparison of the sessions was carried out using Sheffe's post hoc test to identify significant differences between sessions. Statistical treatment was done using SPSS® 13.0 for Windows (LEAD Technologies, 2004).

Results

The group studied has similar anthropometric characteristics; this data is confirmed by low coefficient of variability (CV). Descriptive characteristics and baseline measures of outcome variables are described in Table 1.

Table 1 - Subjects' characteristics

Characteristics	Average \pm SD	Range	CV (%)
Age (years)	24 \pm 5	18-36	20,8
Height (cm)	177 \pm 7	160-188	3,9
Weight (Kg)	73,8 \pm 7,9	59,0-89,5	10,7
LBM (Kg)	63,6 \pm 6,7	52,8-76,4	10,5
Fat %	12,7 \pm 3,5	8,3-19,8	27,6

Fat% - Percentual of body fat; CV – Coeficient of Variation (SD/Average)

The performance in 10RM test was homogeneous (Table 2), this data is important because the microinjuries depend on fitness level.

Table 2 – 10RM performance for each exercise. Due to the exercise equipment design variations, we choose to describe the exercise force as arbitrary units (AU).

Exercise	Load (AU)	CV (%)
Bench Press	48,9 \pm 11,5	23,5
Cable Pulldowns	48,7 \pm 7,5	15,4
Military Press	18,0 \pm 6,8	37,7
Biceps Curl	26,7 \pm 7,0	26,2
Triceps Curl	35,2 \pm 9,4	26,7
Leg Press	103,9 \pm 30,7	29,5
Leg Extension	47,7 \pm 14,2	29,8
Lying Leg Curls	25,0 \pm 7,4	29,6

CV – Coeficient of Variation (SD/Average)

The basal CK concentration is high in comparison to normal population's values (\pm 230 U/L). Creatine kinase was significantly increased from baseline at 24, 48 and 72 hours ($p < 0.05$) postexercise, but there were no differences in creatine kinase between 1min or 3min at any time (figure 1).

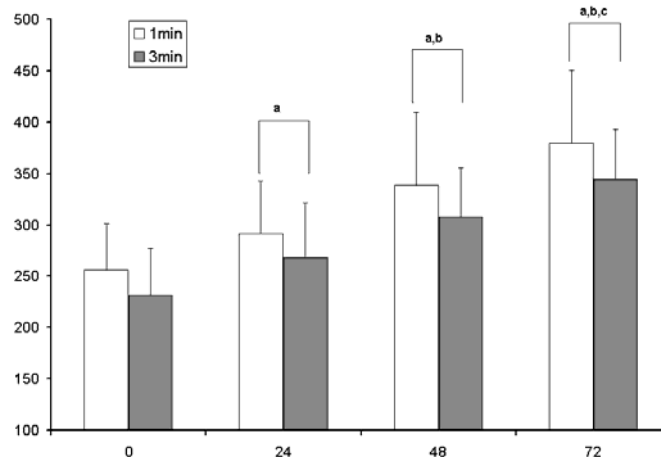


Figure 1 – Creatine kinase (CK) concentrations measured before, 24, 48 and 72h after a training session. (a) Significantly different from 0 value (main effect, $p < 0.05$; group vs time); (b) Significantly different from 24 value (main effect, $p < 0.05$; group vs time); (c) Significantly different from 48 value (main effect, $p < 0.05$; group vs time).

The CK concentration normalized to pre-exercise values showed similar results to absolute values, except in 24h (figure 2). There was no significant difference between sessions with 1 or 3-minute rest interval ($p>0.05$).

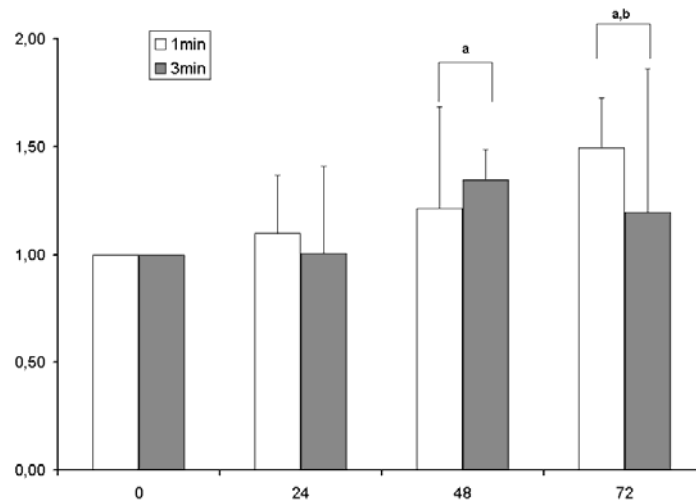


Figure 2 – The CK concentration is normalized (average \pm SE) to pre-exercise values (100%). (a) Significantly different from 0 value (main effect, $p<0.05$; group vs time); (b) Significantly different from 24 value (main effect, $p<0.05$; group vs time).

Discussion

As presented in the introduction, the serum CK concentration serves as an index of both overexertion and adaptation of the muscular system to repeated bouts of exercise. Total CK levels depend on age, gender, muscle mass and physical activity. High levels of serum CK in apparently healthy subjects may be correlated with physical training status, as they depend on sarcomeric damage: strenuous exercise that damages skeletal muscle cells results in increased total serum CK. Total serum CK activity is markedly elevated for 24 h after the exercise bout and it gradually returns to basal levels (72-96h after) when the subject rest. The serum CK activity raised 24h after session training. This effect is prolonged for 48 and 72 h after training session (Mougios, 2007; Brancaccio et al., 2007; Antunes Neto et al., 2007). The present study corroborates previous reports, the CK concentration raise after 24, 48 and 72h after training session.

Mougios (2007) indicate profound effects of training on the reference intervals for serum CK. Reference intervals in athletes and, further, reference intervals according to sport may protect physicians from misinterpreting high CK values as pathological ones. Our data corroborate this findings, basal values is higher in this study because the subjects were physically active.

Previous studies about microinjuries, in general, used just one exercise with a great number of sets or repetitions, this is very rare in sport or recreative resistance training (Clarkson and Hubal, 2002; Nosaka et al., 2002; Brancaccio et al., 2007). The sessions are realized with five to 12 exercises (2-6 sets, 6 to 15 repetitions), the experimental design of the present study is very close

to daily training sessions (ACSM, 2002). In fact, the results confirm to coaches, athletes and recreational weight training practitioners the real values of scientific data.

Usually, exercise training load refers to the dosage to which the subject is exposed. Such dosage is a function of exercise intensity, frequency, and volume of activity performed by the subject. The length of a rest period is an important factor when designing a resistance training session because is verified a great number of physiological, biochemical and hormonal variations. Short intervals rises the lactate concentration, H^+ concentration, NH_3^+ concentrations and decreases serum glucose and muscle/hepatic glycogen stores. Also, Miranda et al (2007) and others, shows that short rest interval decreases the total number of repetitions in a training session. In other hand, high rest intervals can't cause expected physiological adjusts by training. To implement a well designed and scientific based session training plan, it is necessary the best choice of rest intervals.

Matuszak et al. (2003), Simão et al. (2005), Bottaro et al. (2005), Rahimi (2005), Rahimi et al. (2007) and Miranda et al. (2007), in different experimental design, show a decrease in performance when the rest interval is short, i. e., the fatigue is faster the smaller the time to rest. Our data indicates that fatigue comes from mechanisms that are not associated with size of microinjuries. Other physiological, hormonal, biochemical or psychological factors were probably responsible for this phenomenon. It is very important report that the data of this study do not mean that the microinjuries outside the set of factors caused the fatigue, our data allow postulate that the microinjuries are not responsible for the greater difficulty in performing intermittent exercises at shorter rest intervals (1 minute compared to 3 minutes).

Mayhew et al (2005) identified difference in CK serum concentration after 10 sets of 10 repetitions at 65% of 10RM with 1 and 3 min rest interval. However, the bout of 3 min rest interval was always preceded for 1 min rest interval. This fact can have influenced those results due the attenuation response in CK serum to a second bout of exercise performed 1 week after an earlier, identical bout (Ebbeling and Clarkson, 1989; Antunes Neto et al, 2007).

In our study, as well as Mayhew et al (2005), the subjects were accustomed to resistance exercise of the all exercises included. The main difference in these studies is the series of exercise executed and the intensity of exercises, but we used the series of the resistance exercise very close to daily training sessions.

These two rest periods were chosen because previous research indicates that acute physiological responses, including blood lactate, acidosis, cardiovascular, hormone and immunological response, are significantly different between rest periods of 1 and 3 minutes in length (Kraemer et al., 1990; Kraemer et al., 1993; Mayhew et al, 2005; Mavrommatakis et al., 2006). Also Rahimi (2005) and Rahimi et al. (2007) there was no significant difference in training volume completed between the 1- and 2-minute rest conditions.

Conclusion

From the results we can postulate that the mechanical stress caused by the proposed training session cause similar damage in the muscle fibers do not depend of the 1 or 3 minutes of rest interval between series.

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References

- ACSM. (2002) American College of Sports Medicine position stand on progression models in resistance training for healthy adults. *Medicine & Science in Sports & Exercise*, 34, 364–380.
- Antunes Neto, J. M. F., Ferreira, D. C. B. G., Reis, I. C., Calvi, R. G. and Rivera, R. J. B. (2007) Maintenance of cell microinjuries and long term adaptative responses in strength training. *Brazilian Journal of Biomotricity*, 1, 87-102.
- Bassit, R. A., Curi, R. and Costa Rosa, L. F. B. P. (2007) Creatine supplementation reduces plasma levels of pro-inflammatory cytokines and PGE2 after a half-ironman competition. *Amino Acids*, published online October 05, 2007; doi:10.1007/s00726-007-0582-4.
- Bottaro, M., Russo, A. and Oliveira, R. J. (2005) The effects of rest interval on quadriceps torque during an isokinetic testing protocol in elderly. *Journal of Sport Science and Medicine* 4, 285-290.
- Brancaccio, P., Maffulli, N. and Limongelli, F. M. (2007) Creatine kinase monitoring in sport medicine. *British Medical Bulletin*, 81, 209-230.
- Chen, T. C. and Hsieh, S. S. (2001) Effects of a 7-day eccentric training period on muscle damage and inflammation. *Medicine & Science in Sports & Exercise*, 33, 1732–1738.
- Clarkson, P. M. and Hubal, M. J. (2002) Exercise-induced muscle damage in humans. *Am J Phys Med Rehabil*, 81, S52-S69.
- Ebbeling, C. B. and Clarkson, P. M. (1989) Exercise-induced muscle damage and adaptation. *Sports Med.* 7:207-234.
- Hackney, A. C. and Battaglini, C. (2007) The Overtraining Syndrome: Neuroendocrine imbalances in athletes. *Brazilian Journal of Biomotricity*, 1, 34-44.
- Kraemer, W. J., Fleck, S. J., Dziados, J. E., Harman, E. A., Marchitelli, L. J., Gordon, S. E., Mello, R., Frykman, P. N., Koziris, L. P. and Triplett, N. T. (1993) Changes in hormonal

concentrations after different heavy-resistance exercise protocols in women. *J. Appl. Physiol.*, 75, 594–604.

Kraemer, W. J., Marchitelli, L., Gordon, S. E., Harman, E., Dziados, J. E., Mello, R., Frykman, P., Mccurry, D. and Fleck, S. J. (1990) Hormonal and growth factor responses to heavy resistance exercise protocols. *J. Appl. Physiol.*, 69, 1442–1450.

Kraemer, W. J., Noble, B. J., Clark, M. J. and Culver, B. W. (1987) Physiologic responses to heavy-resistance exercise with very short rest period. *Int. J. Sports Med.*, 8, 247–252.

Kraemer, W. J. and Ratamess, N. A. (2004) Fundamentals of Resistance Training: progression and Exercise Prescription. *Medicine & Science in Sports & Exercise*, 36, 674–688.

Larson, G. D., y Potteiger, J. A. A. (1997) Comparison of three different rest intervals between multiple squat bouts. *Journal of Strength and Conditioning Research*, 11, 115–118.

Matuszak, M.E., Fry, A. C., Weiss, L. W., Ireland, T. R. and Mcknight, M. M. (2003) Effect of rest interval length on repeated 1 repetition maximum back squats. *Journal of Strength and Conditioning Research*, 17, 634–637.

Mavrommatakis, E., Bogdanis, G. C., Kaloupsis, S. and Maridaki, M. (2006) Recovery of power output and heart rate kinetics during repeated bouts of rowing exercise with different rest intervals *Journal of Sport Science and Medicine*, 5, 115-122.

Mayhew, D. L., Thyfault, J. P. and Koch A. J. (2005) Rest-interval length affects leukocyte levels during heavy resistance exercise. *Journal of strength and conditioning research*, 19, 16-22.

Miranda, H., Fleck, S. J., Simão, R., Barreto, A. C., Dantas, E. H. M. and Novaes, J. (2007) Effect of two different rest period lengths on the number of repetitions performed during resistance training. *Journal of Strength and Conditioning Research*, 21, 1032–1036.

Mougios, V (2007) Reference intervals for serum creatine kinase in athletes. *Br J Sports Med*, 41, 674-678.

Nosaka, K., Newton, M. and Sacco, P. (2002) Muscle damage and soreness after endurance exercise of the elbow flexors. *Medicine & Science in Sports & Exercise*, 34, 920–927.

Pearson, D., Feigenbaum, A., Conley, M. and Kraemer, W. (2000) The National Strength and Conditioning Association's basic guidelines for the resistance training of athletes. *Journal of Strength and Conditioning Research*, 22, 14–27.

Phillips, T., Childs, A. C., Dreon, D. M., Phinney, S. and Leeuwenburgh, C. (2003) A Dietary Supplement Attenuates IL-6 and CRP after Eccentric Exercise in Untrained Males. *Medicine & Science in Sports & Exercise*, 35, 2032–2037.

Ribeiro, V.; Pereira, R.; Machado, M.; (2008). Resistance Exercise-Induced Microinjuries do not Depend on 1 or 3 Minutes Rest Time Interval Between Series. *Revista Internacional de Ciencias del Deporte*. 13(4), 44-53. <http://www.cafyd.com/REVISTA/01304.pdf>

Pollock, M. L., Gaesser, G. A., Butcher, J. D., Despres, J. D., Dishman, R. K., Franklin, B. A. and Garber, C. E. (1998) The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Medicine & Science in Sports & Exercise*, 30, 975–991.

Rahimi, R. (2005) Effect of different rest intervals on the exercise volume completed during squat bouts. *Journal of Sport Science and Medicine*, 4, 361-366.

Rahimi, R., Sadeghi Boroujerdi, S., Ghaeeni, S. and Reza Noori, S. (2007) The Effect of Different Rest Intervals between Sets on the Training Volume of Male Athletes. *Facta Universitatis*, 5, 37-46

Rawson. E. S., Gunn, B. and Clarkson, P. M. (2001) The effects of creatine supplementation on exercise-induced muscle damage. *Journal of Strength and Conditioning Research*, 15, 178-184.

Richmond, S. R. and Godard, P. M. (2004) The effects of varied rest periods between sets to failure using the bench press in recreationally trained men. *Journal of Strength and Conditioning Research*, 18, 846–849.

Simão, R., Farinatti, P. T. V., Polito, M. D., Maior, A. S. and Fleck, S. J. (2005) Influence of exercise order on the number of repetitions performed and perceived exertion during resistive exercises. *Journal of Strength and Conditioning Research*, 11, 152–156.

Stupka, N., Lowther, S., Chorneyko, K., Bourgeois, J. M., Hogben, C. and Tarnopolsky, M. A. (2000) Gender differences in muscle inflammation after eccentric exercise. *J Appl Physiol*, 89, 2325–2332.

Tidball, J. G. (2005) Inflammatory processes in muscle injury and repair. *Am J Physiol Regul Integr Comp Physiol*, 288, R345-R353.