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COMPARISON OF ACUTE RESPONSES TO FOUR DIFFERENT HYPERTROPHY-ORIENTED RESISTANCE TRAINING METHODOLOGIES

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ABSTRACT

Muscle hypertrophy has been associated with both athletic performance and quality of life. Although hypertrophy-oriented resistance training methodologies are very popular, it is still unclear the different physiological and perceptual responses to some of these methodologies. The aim of this study was to compare the acute effects of four different hypertrophy-oriented resistance training methodologies. During four weeks, seventeen participants with experience in resistance training performed a once-a-week resistance training session, differing the methodology (traditional, pyramid, agonist supersets and reciprocal supersets). Acute responses to the different training sessions were measured via lactate concentration, peak velocity losses, rating of perceived exertion, and number of assisted repetitions. Both lactate concentration and rating of perceived exertion showed that the reciprocal supersets caused greater values compared with either the traditional or the pyramid methodologies. Although all of the methodologies led to significant decreases in peak velocity, these decreases were not different between methodologies. The results of the present study highlight the reciprocal supersets as being the most stressed methodology when talking about acute fatigue responses to a single training session. Further research is required to evaluate if these large acute fatigue effects could lead to greater muscle hypertrophy following a training intervention.

Key words: muscle, hypertrophy, strength, fatigue

COMPARACIÓN DE RESPUESTAS AGUDAS A CUATRO METODOLOGÍAS DIFERENTES DE ENTRENAMIENTO DE LA FUERZA ORIENTADAS A LA HIPERTROFIA

RESUMEN

La hipertrofia muscular ha sido asociada tanto con un mejor rendimiento deportivo como con una mejor calidad de vida. Aunque las metodologías de entrenamiento orientadas a la hipertrofia son muy populares, todavía no están claras las diferentes respuestas fisiológicas y perceptivas provocadas por varias metodologías. El objetivo de este estudio fue comparar los efectos agudos de cuatro metodologías diferentes de entrenamiento orientadas a la hipertrofia. Durante cuatro semanas, diecisiete participantes con experiencia en el entrenamiento de fuerza realizaron una sesión de entrenamiento semanal, difiriendo en la metodología utilizada (tradicional, pirámide, superseries recíprocas y superseries agonistas). Las respuestas agudas a las cuatro sesiones fueron medidas a través de la concentración de lactato, pérdidas en la velocidad del movimiento, percepción de esfuerzo subjetiva y número de repeticiones asistidas. Tanto la concentración de lactato como la percepción de esfuerzo mostraron que las superseries recíprocas causaron mayores valores comparado con la metodología tradicional y la pirámide. Aunque todas las metodologías conllevaron una pérdida significativa en la velocidad de movimiento, este descenso no fue diferente entre metodologías. Los resultados de este estudio destacan a la metodología de superseries recíprocas como la más estresante en cuanto a efectos de fatiga aguda tras una sesión de entrenamiento. Son necesarias más investigaciones para evaluar si este incremento en los efectos agudos de fatiga podría conllevar un mayor incremento de masa muscular tras un periodo de intervención.

Palabras clave: músculo, hipertrofia, fuerza, fatiga

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INTRODUCTION

Strength training is a key component when aiming to improve both athletic performance and quality of life. Independently of age or gender, most people are able to follow a regular resistance training programme (Bird, Tarpenning, & Marino, 2005) due to the demonstrated efficacy shown by resistance training to maintain or increase both the strength and the muscle cross-sectional area (CSA) (Haas, Faigenbaum, & Franklin, 2001). However, resistance training prescription is complex, as it involves the adjustment of variables that influence such training based on the outcome desired. Among the variables influencing a resistance training programme, intensity, volume, density, rest interval, exercise selection and movement velocity are commonly included (Kraemer, 1983).

Among the multiple goals that can be sought with resistance training, one of them is muscular hypertrophy, defined as an increase in the CSA of the skeletal muscle (Schoenfeld, 2010). An optimal CSA has been related to improvements in neuromuscular performance, such as force production and intermuscular coordination (Maughan , Watson, & Weir, 1983). Thus, muscle development is especially important, not only to optimise performance in different sport activities, but also when aiming at improving health parameters, such as preventing sarcopenia (de Groot, van Loon, Verdijk, Snijders, & Tieland, 2014).

Standards of hypertrophy-oriented resistance training mainly depend on the participant experience. Consequently, the American College of Sports Medicine (ACSM) has suggested training intensities ranging between 70% and 85% of a repetition maximum (1 RM) for inexperienced or moderately experienced participants, while the intensity needed for experienced participants may be higher, even achieving a 100% of the 1 RM. When talking about the training session volume, one to three sets of 8–12 repetitions have been recommended for low experienced participants, while recommendations for experienced participants involve three to six sets of 6–12 repetitions. Finally, a one- to two-minute rest interval between sets is usually employed when training with hypertrophy-oriented methodologies (ACSM, 2009).

An in-depth study carried out with highly experienced resistance training participants –provided insight into the most typically-used methodologies (Hackett, Johnson, & Chow, 2013). This study highlighted the fact that the most used hypertrophy-oriented sessions consisted of three to six sets per exercise, performing 7–9 RM, and using one to two min rest intervals. In addition to these basic rules, a significant number of resistance training methodologies aimed at muscle development have been developed. Nevertheless, a paucity of research has examined both the acute and chronic responses entailed by such methodologies (Schoenfeld, 2011).

Hackett et al. (2013) showed that after the traditional (above-mentioned) methodology, the most used hypertrophy methodologies are the pyramid (64% of survey respondent) and the supersets (61%). These are used far more often than are forced repetitions, drop sets or partial repetitions. Pyramid methodology involves intensity and volume variations between sets, showing increases in intensity while volume decreases or vice versa. The methodology based on supersets combine two exercises without rest, having two different ways of carrying out this mode of training. First, in the agonist supersets, the couple of exercises performed without rest involve the same musculature in different exercises (e.g. "squat" + "leg extension"). On the other hand, reciprocal supersets include exercises of action-opposed movements (e.g. "leg curl" + "leg extension"). In spite of the popularity of these methodologies, not much is known about either the acute or the chronic responses entailed by each kind of training, even though it is considered as a specialised method for highly trained participants (Schoenfeld, 2011). Therefore, the aim of this study was to quantify and compare, through different variables (physiological and perceptual), the acute fatigue caused by four different hypertrophy-oriented resistance training methodologies.

METHOD

Participants

Seventeen physically active males (23.2 ± 3.6 years), voluntarily participated in the study. Inclusion criteria required that participants had at least two years of resistance training experience, andan RM in the bench press greater than 100 kg, thus being considered as experienced participants according to the literature (Schoenfeld, Peterson, Ogborn, Contreras, & Sonmez, 2015). In addition, all participants needed to have previously performed, at least once, a session of each of the methodologies used in the study. All participants were instructed to maintain their normal lifehabits. Throughout the investigation, participants were requested to maintain their regular diets and normal hydration, not to take any nutritional supplementation or anti-inflammatory medications, and to refrain from caffeine intake during the three hours before each testing session. Strength training sessions were not allowed at least 72 hours prior to the experimental sessions. Before participation, each participant provided written informed consent approved by the Ethics Committee of the University Miguel Hernández of Elche in accordance with the Declaration of Helsinki.

Measures

Maximal dynamic strength assessment. One week before the first and the third experimental sessions, participants carried out two maximal dynamic strength sessions (four exercises per session) separated by 72 h. In the first session, the exercises evaluated were the bench press, lateral pull down, leg extension, and seated leg curl, while in the second sessions the exercises were incline bench press, seated row, leg press and lying leg curl. These maximal dynamic strength assessment sessions were performed with the aim of adjusting training intensities in case of changes in participants' 1 RM during such periods. The 1 RM bench press was assessed using a previously established protocol (Earle, & Baechle, 2004), which required that participants progressively increased the resistance across attempts until the 1 RM was achieved. The rest period between trials was at least five minutes. The same researcher conducted all testing and all conditions were standardised.

Training sessions. Training intensity during all sets when using the traditional and the reciprocal superset methodologies was set at 70% of 1 RM, which was similar to other studies (Kelleher, Hackney, Fairchild, Keslacy, & Ploutz-Snyder, 2010; Smilios, Pilianidis, Karamouzis, & Tokmakidis, 2002). For the agonist superset methodology, the intensity was 60% of 1 RM, with the goal of having the participants reach a number of repetitions close to 10 during the second exercise. This decision was made following a pilot study that showed that, when using the 70% of 1 RM guideline, participants were not able to complete at least the 50% of the volume in the second set of each pair of exercises. Finally, in the reversed pyramid methodology, the intensity decreased from 80% (first set) to 60% (last set) of 1 RM. Total volume of each training session was matched to 240 repetitions, while rest intervals between sets were set at 90 s (Schoenfeld, Ratamess, Peterson, Contreras, Sonmez, & Alvar, 2014). Finally, repetition execution was performed in a cycle of 2 s for the concentric phase and 2 s for the eccentric phase in all of the exercises.

TABLE 1
Training sessions volume and intensity by methodology.

Methodology	Exercises	Sets	Repetitions	Intensity
Traditional	4	6	10	70%
Reciprocal supersets	4	6	10	70%
Agonist supersets	8	3	10	60%
Pyramid	4	6	6, 8, 10, 10, 12, 14	80%, 75%, 70%, 70%, 65%, 60%

Lactate concentration [La⁻]. [La⁻] was determined from 25 µl capillarised blood samples drawn from the earlobe and were analysed using a portable device (Lactate Scout, Senselab, Germany) with an accuracy of 0.1 $mmol \cdot L^{-1}$(Tanner, Fuller, & Ross, 2010). Samples were taken one minute before and after each protocol and were analysed at these time points using the portable lactate analyser.

Peak velocity. Pre- and post-session peak velocity values were recorded by means of a single set of five repetitions in the bench press throw exercise performed using a Smith machine (Technogym, Gambettola, Italy) with a load representing 40% of the individuals' 1 RM. Kinematic data were recorded by linking a rotary encoder to one end of the bar (T-Force system, Ergotech, Spain), which recorded the position of the bar with an analog-to-digital conversion rate of 1000 Hz and an accuracy of 0.0002 m. The linear transducer was interfaced to a personal computer by means of a 14-bit analog-to-digital data acquisition board, where a specialised software application (T-Force Dynamic Measurement System) automatically calculated the relevant kinematic and kinetic parameters. Bar velocity was calculated using differentiation of bar displacement data with respect to time. Peak velocity was taken as the maximum value of the velocity–time curve. The validity and reliability of this system was previously established, with ICC values ranging from 0.81 to 0.91 and a coefficient of variation < 3.6% (Marques & Izquierdo, 2014). For data analysis, the decrease in peak velocity between the value of the pre- and post-test sets was used.

Rating of perceived exertion. RPE values were obtained using the Borg category scale (CR-10) (Borg, 1990). The CR-10 scale consists of a scale of exercise intensity defined between "rest" (0) and "maximal" (10). Participants were asked "how hard do you feel the exercise was?" immediately after the last set of each training session.

Assisted repetitions. Due to the fact that the training volume was equalised in the four different methodologies, the total number of assisted repetitions [repetitions in which the participant needed external help (i.e. main researcher) to complete it] within each training session was quantified and used as a measure of acute fatigue.

Procedure

An experimental protocol was designed to evaluate the acute fatigue caused by four different hypertrophy-oriented resistance training methodologies: traditional, pyramid, agonist supersets, and reciprocal supersets. To do this, on four consecutive Mondays, 17 participants attended four different hypertrophy-oriented training sessions with at least 72 h of rest period after any other fitness activity. During each session, participants performed a different methodology, with the order of the methodologies balanced between participants. The acute fatigue evoked by the different methodologies was evaluated by: (1) lactate concentration ([La^-]), (2) peak velocity decreases in the bench press, (3) rating of perceived exertion (RPE; CR-10), and (4) number of assisted repetitions.

Statistical analysis

All data were analysed using the statistical package SPSS 18.0 (SPSS Inc., Chicago, IL, USA). After verifying the normality of the outcome measures using the Kolmogorov-Smirnov test, a one-way repeated measures ANOVA was used to evaluate the influence of the different training methodologies on (a) [La$^-$], (b) peak power decreases, (c) CR-10 scale, and (d) assisted repetitions. Statistical significance was set at $p < 0.05$. In addition, Cohen's d and the standardised mean difference were used to calculate the effect sizes (ES; mean difference/pooled SD), interpreted as d< 0.2 (trivial), 0.2–0.5 (small), 0.5–0.8 (moderate), and > 0.8 (large).

RESULTS

Lactate concentration [La$^-$]. [La$^-$] was significantly different depending on the training methodology used. Thus, when participants performed both the agonist supersets (12.1 ± 2.6 mmol·L^{-1}) and reciprocal supersets (12.4 ± 2.5 mmol·L^{-1}), [La$^-$] was significantly higher compared to either the traditional (9.5 ± 2.0 mmol·L^{-1}; d = 1.18 and 1.21 respectively) or pyramid (10 ± 2.2 mmol·L^{-1}; d = 0.88 and 0.95 respectively) methodologies.

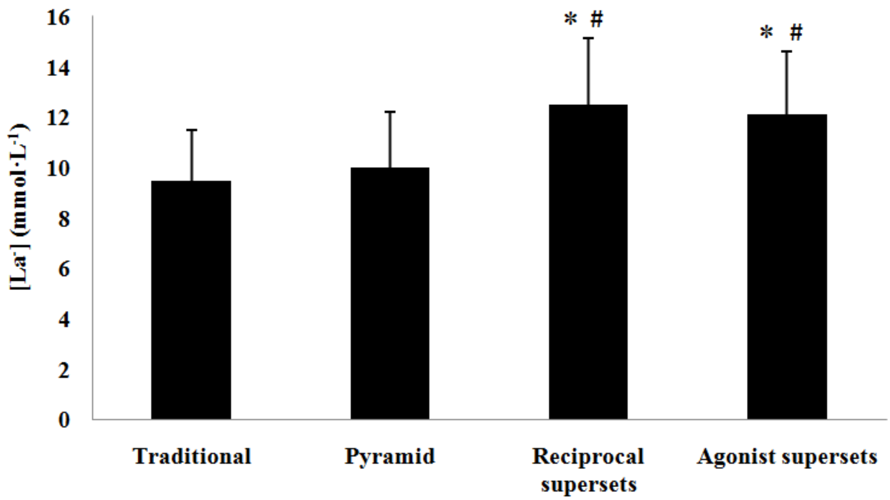

FIGURE 1: Lactate concentrations after each hypertrophy-oriented resistance training session (* = significant difference with traditional methodology; # = significant difference with pyramid methodology).

Peak velocity decreases. In spite of the fact that all of the methodologies led to significant decreases in peak velocity when comparing pre-and post-session values, these decreases were not significantly different between methodologies. Specifically, peak velocity decreases were: 15.7 ± 12.9% (traditional), 13.1 ± 9.5% (pyramid), 14.5 ± 7.5% (reciprocal supersets), and 10.5 ± 10.8% (agonist supersets).

Rating of perceived exertion (CR-10). Both agonist and reciprocal supersets entailed higher CR-10 values compared with traditional and pyramid methodologies. Concretely, CR-10 values during the reciprocal supersets (8.4 ± 0.9) and agonist supersets (7.9 ± 1.4) were significantly greater than were those with the pyramid methodology (7 ± 1.7; d = 1.03 and 0.58, respectively). In addition, the reciprocal supersets methodology also showed significantly greater values compared with the traditional methodology (7.2 ± 1.3; d = 1.07).

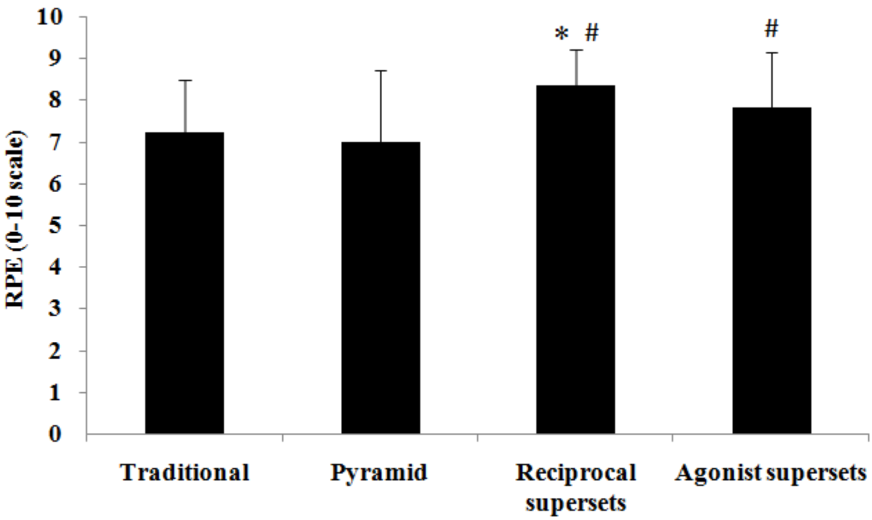

FIGURE 2: RPE values after each hypertrophy-oriented resistance training session. (* = significant difference with traditional methodology; # = significant difference with pyramid methodology).

Assisted repetitions. The total number of assisted repetitions was significantly different between methodologies. Thus, when using the traditional methodology, participants required assistance with a higher number of repetitions compared to both the pyramid (30 ± 13.5 vs. 21.6 ± 14.7 repetitions; d = 0.58) and the agonist supersets (30 ± 13.5 vs. 20.8 ± 10.6 repetitions; d = 0.75). Furthermore, the reciprocal superset methodology caused a greater number of assisted repetitions compared with the pyramid methodology (28.3 ± 16.5 vs. 21.6 ± 14.7 repetitions; d = 0.43).

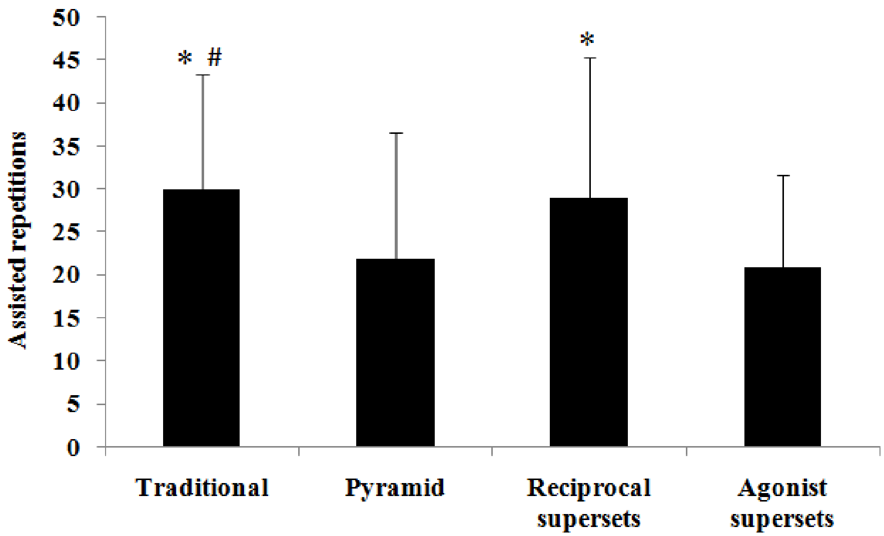

FIGURE 3: Number of assisted repetitions required during each hypertrophy-oriented resistance training session. (* = significant difference with traditional methodology; # = significant difference with pyramid methodology).

DISCUSSION

The aim of this study was to analyse the acute effects of four different hypertrophy-oriented strength training methodologies. The results obtained in the current study indicate that the reciprocal superset methodology leads to a greater training load (i.e. RPE values, [La$^-$]) compared with the other studied methodologies.

The [La$^-$] values found in the present study when using the reciprocal supersets (12.5 mmol·L^{-1}) and the traditional methodology (9.5 mmol·L^{-1}) are in line with Kelleher et al.'s (2010) findings, which found values of 11.7 and 8.8 mmol·L^{-1} for the reciprocal supersets and the traditional methodology, respectively. In addition, Carregaro, Cunha, Oliveira, Brown, & Bottaro (2013) also found greater lactate values when comparing the reciprocal supersets with the traditional methodology. Thus, the results found in the current study are in line with these findings, as the reciprocal superset methodology entailed greater [La$^-$] compared with both the traditional and the pyramid methodologies. However, the results of [La$^-$] found in the present study do not allow for discriminating between the effect of either reciprocal or agonist supersets, as both methodologies showed very similar responses.

Although velocity loss in the bench press exercise has been used as a good indicator of neuromuscular fatigue (Sánchez-Medina & González-Badillo, 2011), decreases in peak velocity during the bench press throw exercise in the current study did not show differences between any methodology. These results differ from Paz et al.'s (2015) results, which found greater neuromuscular fatigue in the primary agonist muscles of both the bench press and the seated row exercise when comparing the reciprocal supersets with traditional methodology. Indeed, Paz et al. (2015) found between-methodology differences in acute neuromuscular fatigue by measuring the muscle activity immediately after performing sets of a given exercise. Therefore, we expected greater decreases in peak power values in the most neuromuscular stressful methodology. It is possible that the sessions' schedule, where first the exercises of the upper body were performed followed by the lower body exercises, could have hidden differences in peak power decreases between the four training methodologies. Thus, it could be the reason for the peak velocity decreases found in the present study, which were significantly lower (i.e. 10–15%) than those found by Sánchez-Medina & González-Badillo (30%) after three sets of 12 RM.

Data of the perceived exertion variable measured in our study (CR-10 scale) agreed with the findings of previous studies with resistance-training experienced participants after training until repetition failure. Hence, Simao et al. (2007) and Singh, Foster, Tod, & McGuigan (2007) reported values of 7.5 and 8.5, respectively, while in the current study, the CR-10 values ranged from 7 to 8.5 points. The usefulness of rating perceived exertion variables to control training session intensity was previously reported (Robertson et al., 2003). Consequently, similar to physiological data (i.e. [La^-]), the reciprocal superset methodology showed greater values compared to the more traditional training methodologies, highlighting the higher stress impact caused by this methodology.

The analysis of volume completed is a commonly used variable to quantify the acute effect of resistance training sessions. Aimed at equalising the total number of repetitions performed in each training session, we decided to record the number of assisted repetitions after having achieved muscular failure. Opposite to other fatigue variables measured in the present study, the traditional methodology showed greater values for assisted repetitions, although there were no differences when compared with the reciprocal supersets methodology. Paz et al. (2015) found similar results when participants completed a lower number of repetitions during training under the traditional methodology. The lower volume completed when using the traditional methodology compared with the reciprocal supersets could be explained by the greater rest duration between exercises of the same musculature in the last methodology. Nevertheless, our results are in disagreement with Maia, Willardson, Paz, & Miranda (2014), who found that participants were able to perform a greater number of repetitions after completing a set of the antagonist musculature exercises. It should be highlighted that differences in the training protocol (a single set vs. multiple sets) may explain such results. Furthermore, due to accumulated fatigue over the sets, these results may change. On the other hand, lower force levels have been reported in the agonist musculature after reciprocal activation at lower velocities (similar to hypertrophy-oriented training movements) (Maynard & Ebben, 2003). The higher number of assisted repetitions found in our study when using the reciprocal superset methodology compared with pyramid and agonist supersets (although non-significant with the last one) may be explained by the accumulated fatigue caused by such slow velocity movements. It should be noted that a higher number of assisted repetitions within a resistance training session has been related to a longer duration before reaching muscular failure. This could lead to greater hormonal responses (i.e. growth hormone), and consequently, may enhance muscle hypertrophy processes triggered by resistance training (Kraemer et al., 1990). From this point of view, both the traditional and reciprocal superset methodologies supposed a greater stimulus for muscular hypertrophy.

The present study presents some limitations. For example, the variables used to quantify acute fatigue are indirect, and the use of biomarkers in either blood or urine, the analysis of energy expenditure during and and after the session, or EMG measurements could heavily contribute to confirmation of the study’s findings. Additionally, although acute effects are practically interesting, longitudinal studies aimed at determining chronic adaptations when using different hypertrophy-oriented resistance training methodologies are required.

CONCLUSIONS

The acute effects of different hypertrophy-oriented training methodologies on variables related to metabolic ([La^-]), perceived (CR-10), kinetic (velocity losses) and training volume (assisted repetitions) aspects underline the reciprocal supersets as the most demanding methodology compared with either the traditional, the pyramid, or the agonist supersets methodologies. Nevertheless, the effect of these different methodologies on various populations (e.g. untrained or elite athletes) could lead to different results, as varied responses based on an athlete's experience have been previously reported. Finally, further research is needed to evaluate if these different acute responses can influence chronic adaptations when different hypertrophy-oriented training methodologies are used.

References

American College of Sports Medicine (ACSM). (2009). Progression models in resistance training for healthy adults. *Medicine and Science in Sports and Exercise, 41(3)*, 687-708. doi: 10.1249/MSS.0b013e3181915670

Bird, S. P., Tarpenning, K. M., & Marino, F. E. (2005). Designing resistance training programmes to enhance muscular fitness: A review of the acute programme variables. *Sports Medicine, 35*, 841-851. doi: 10.2165/00007256-200535100-00002

Borg, G. (1990). Psychophysical scaling with applications in physical work and the perception of exertion. *Scandinavian Journal of Work and Environment Health*, 16(1), 55-58. doi: 10.5271/sjweh.1815

Carregaro, R., Cunha, R., Oliveira, C. G., Brown, L. E., & Bottaro, M. (2013). Muscle fatigue and metabolic responses following three different antagonist pre-load resistance exercises. *Journal of Electromyography and Kinesiology, 23*, 1090-1096. doi: 10.1016/j.jelekin.2013.04.010

de Groot, C. P., van Loon, L. J., Verdijk, L., Snijders, T., & Tieland, C. A. (2014). Strategies to augment muscle mass in elderly; the role of exercise, nutrition, and muscle stem cells. *Proceedings of the ICFSR, 3*, 26-27.

Earle, R. W., & Baechle, T. R. (2004). *NSCA's essentials of personal training*. Champaign, IL: Human Kinetic.

Hackett, D. A., Johnson, N. A., & Chow, C. M. (2013). Training practices and ergogenic aids used by male bodybuilders. *Journal of Strength and Conditioning Research, 27(6)*, 1609-1617. doi: 10.1519/JSC.0b013e318271272a

Hass, C. J., Feigenbaum, M. S., & Franklin, B. A. (2001). Prescription of resistance training for healthy populations. *Sports Medicine, 31*, 953-964. doi: 10.2165/00007256-200131140-00001

Kelleher, A. R., Hackney, K. J., Fairchild, T. J., Keslacy, S., & Ploutz-Snyder, L. L. (2010). The metabolic costs of reciprocal supersets vs traditional resistance exercise in young recreationally active adults. *Journal of Strength and Conditioning Research, 24*, 1043–1051. doi: 10.1519/JSC.0b013e3181d3e993

Kraemer, W. J. (1983). Exercise prescription in weight training: Manipulating program variables. *Journal of Strength and Conditioning Research*, 5, 58-61.

Kraemer, W. J., Marchitelli, L., Gordon, S. E., Harman, E., Dziados, J. E., Mello, R., Frykman, P., McCurry, D., & Fleck, S. J. (1990). Hormonal and growth factor responses to heavy resistance exercise protocols. *Journal of Applied Physiology, 69*, 1442-1450.

Maia, M. F., Willardson, J. M., Paz, G. A., & Miranda, H. (2014). Effects of different rest intervals between antagonist paired sets on repetition performance and muscle activation. *Journal of Strength and Conditioning Research, 28(9)*, 2529-2535. doi: 10.1519/JSC.0000000000000451

Marques, M. C., & Izquierdo, M. (2014). Kinematic and kinetic associations between vertical jump performance and 10 meters sprint time. *Journal of Strength and Conditioning Research, 28(8)*, 2366-2371. doi: 10.1519/JSC.0000000000000390

Maughan, R. J., Watson, J. S., & Weir, J. (1983). Strength and cross-sectional area of human skeletal muscle. *Journal of Physiology, 338*, 37-49.

Maynard, J., & Ebben, W. (2003). The effects of antagonist prefatigue on agonist torque and electromyography. *Journal of Strength and Conditioning Research 17*, 469-474. doi: 10.1519/00124278-200308000-00007

Paz, G., Robbins, D. W., de Oliveira, C. G., Bottaro, M., Miranda, H., Janeiro, R. J., & Robbins, D. (2015). Volume, load, and neuromuscular fatigue during an acute bout of agonist-antagonist paired-set versus traditional-set training. *Journal of Strength and Conditioning Research.* doi: 10.1519/JSC.0000000000001059

Robertson, R. J., Goss, F. L., Rutkowski, J., Lenz, B., Dixon, C., Timmer, J., Frazee, K., Dube, J., & Andreacci, J. (2003). Concurrent validation of the OMNI perceived exertion scale for resistance exercise. *Medicine and Science in Sport and Exercise, 35(2)*, 333-341. doi: 10.1249/01.MSS.0000048831.15016.2A

Sánchez-Medina, L., & González-Badillo, J. J. (2011). Velocity loss as an indicator of neuromuscular fatigue during resistance training. *Medicine and Science in Sport and Exercise*, *43(9)*, 1725-1734. doi: 10.1249/MSS.0b013e318213f880

Schoenfeld, B. J. (2010). The mechanisms of muscle hypertrophy and their application to resistance training. *Journal of Strength and Conditioning Research, 24(10)*, 2857-2872. doi: 10.1519/JSC.0b013e3181e840f3

Schoenfeld, B. J. (2011) The use of specialized training techniques to maximize muscle hypertrophy. *Strength and Conditioning Journal, 33(4)*, 60-65. doi: 10.1519/SSC.0b013e3182221ec2

Schoenfeld, B. J., Peterson, M. D., Ogborn, D., Contreras, B., & Sonmez, G. T. (2015). Effects of low-versus high-load resistance training on muscle strength and hypertrophy in well-trained men. *Journal of Strength and Conditioning Research, 29(10)*, 2954-2963. doi: 10.1519/JSC.0000000000000958

Schoenfeld, B. J, Ratamess, N. A., Peterson, M. D., Contreras, B., Sonmez, G. T., & Alvar, B. A. (2014). Effects of different volume-equated resistance training loading strategies on muscular adaptations in well-trained men. *Journal of Strength and Conditioning Research, 28(10)*, 2909-2918. doi: 10.1519/JSC.0000000000000480

Singh, F., Foster, C., Tod, D., & McGuigan, M. R. (2007). Monitoring different types of resistance training using session rating of perceived exertion. *International Journal of Sports Physiology and Performance, 2(1)*, 34-45. doi: http://dx.doi.org/10.1123/ijspp.2.1.34

Smilios I, Pilianidis T, Karamouzis M., Tokmakidis SP. Hormonal responses after various resistance exercise protocols. Med Sci Sports Exerc, 2003; 35(4), 644-654. doi: 10.1249/01.MSS.0000058366.04460.5F

Tanner, R. K., Fuller, K. L., & Ross, M. L. (2010). Evaluation of three portable blood lactate analysers: Lactate Pro, Lactate Scout and Lactate Plus. *European Journal of Applied Physiology, 109*, 551-559. doi: 10.1007/s00421-010-1379-9