ORIGINAL ARTICLE

Acute effects of the sequence of concurrent high-intensity resistance and endurance exercises in recreational athletes

Fernando González-Mohíno. *Sport Training Laboratory. University of Castilla-La Mancha. Toledo, Spain. Faculty of Life and Natural Sciences. Nebrija University. Madrid, Spain.*
Victor Rodrigo-Carranza. *Sport Training Laboratory. University of Castilla-La Mancha. Toledo, Spain.*
Daniel Juárez Santos-García. *Sport Training Laboratory. University of Castilla-La Mancha. Toledo, Spain.*
Anthony P. Turner. *Sport, Physical Education and Health Sciences. University of Edinburgh. United Kingdom.*
José María González-Ravé . *Sport Training Laboratory. University of Castilla-La Mancha. Toledo, Spain.*

ABSTRACT

This study aimed to assess the acute effects of the sequence of concurrent training (CT) on physiological, neuromuscular, and perceptive parameters in recreational athletes. Eighteen active men (mean ± SD: 22.00 ± 2.00 years; 79.40 ± 9.87 kg and 175.62 ± 6.35 cm) performed two CT sessions consisting of repeated sprint endurance exercise followed by resistance exercise (E-R) or the reverse sequence (R-E) in a randomized order. The E exercise consisted of 6x30s of cycling "*all-out*" interspersed by 15s of passive recovery, while the R exercise consisted of 3x15 repetitions near failure (1 repetition in reserve) of back squat exercise with rest intervals of 45s. Height in CMJ, heart rate (HR), rating of perceived exertion (RPE) after each exercise, and at the final of the session (sRPE) were recorded. The R-E sequence showed a higher HR at 10s, 1min and 6min ($p < .05$) post E exercise compared to R exercise. Significant protocol x time interactions were observed for sRPE ($p < .001$) being higher after the R-E sequence compared to E-R sequence. RPE was significantly higher ($p < .01$) after E exercise compared to R exercise in both sequences, without differences between the E exercises. However, there were significant differences between the R exercises ($p < .01$) being higher in the R-E sequence. Our results suggest that the order of exercises during CT affects the second exercise when performed in a R-E sequence, with more cardiovascular stress and higher perceived exertions.
Keywords: Sport medicine, Acute fatigue, Training order, High intensity, Strength training.

Cite this article as:
González-Mohíno, F., Rodrigo-Carranza, V., Juárez Santos-García, D., Turner, A. P., & González-Ravé, J. M. (2025). Acute effects of the sequence of concurrent high-intensity resistance and endurance exercises in recreational athletes. *Journal of Human Sport and Exercise, 20*(1), 228-237. https://doi.org/10.55860/9a326a77

Corresponding author. *Sport Training Laboratory. University of Castilla-La Mancha. Avenida Carlos III s/n, 45071 Toledo, Spain.*
E-mail: josemaria.gonzalez@uclm.es
Submitted for publication July 09, 2024.
Accepted for publication August 13, 2024.
Published October 30, 2024.
Journal of Human Sport and Exercise. ISSN 1988-5202.

doi: https://doi.org/10.55860/9a326a77

INTRODUCTION

The combination of resistance and endurance training in the one training program has been known as concurrent training (CT). Variables such as intensity, volume, exercise sequence, exercise mode and recovery period are used by coaches for obtaining the optimal training stimulus. Optimal physiological stress is necessary to progress to increasing training loads according to the overload principle. However, an insufficient recovery period could compromise the training adaptation (Fry et al., 1992), as for example, between resistance and endurance efforts. Therefore, the influence of the between-session recovery periods during CT could have implications about an impaired quality of endurance and resistance training sessions. In relation to the exercise sequence, residual fatigue has been found in the second exercise due to the previous one (Eddens et al., 2018), being able to generate an interference (Hickson, 1980). At the same time, the interference effect of the exercise sequence could be more relevant when high-intensity efforts have been performed during the CT session. For example, previous study (Jones et al., 2017) found and acute unfavourable response by performing endurance exercise prior to resistance exercise when this last one was conducted with high loads. Leveritt and Abernethy (Leveritt & Abernethy, 1999) found an impairment on resistance activity when high-intensity endurance exercise is performed before, mainly explained by an increase of blood lactate and reduction of isokinetic torque. Indeed, repeated sprints may promote acute interferences on resistance exercise, and it has been suggested that sprint-activities must be isolated from resistance training and it would be necessary an adequate recovery time (Coffey et al., 2009). However, it is remaining unknown the acute effects of the reverse order (endurance and resistance exercise) with high-intensity endurance effort. Regarding the resistance exercise performed before the endurance exercise, the resistance exercise with a high velocity loss (40%) induced higher metabolic, mechanical stress and residual fatigue on the subsequent endurance exercise performance (Nájera-Ferrer et al., 2021), being dependent of the level of fatigue (compared to 20% of velocity loss). These authors suggested that high-fatigue resistance exercise before endurance exercise should be avoided.

The countermovement squat jump (CMJ) height loss is used for monitoring the levels of fatigue during a training session (Jimenez-Reyes et al., 2016; Sanchez-Medina & González-Badillo, 2011) due to the strong correlations (0.92-0.97) observed between jump height loss and blood lactate and ammonia. In addition, heart rate (HR) recovery is suggested to be a marker of physical fitness (Shetler et al., 2001). Besides, it is used as a measure of training-induced disturbances in autonomic control. It allows quantifying the autonomic nervous system recovery after a high-intensity exercise (Borresen & Lambert, 2008). The HR recovery is slower than after submaximal exercise, contributing to the deceleration of HR after the cessation of exercise (Kannankeril et al., 2004). On the other hand, the rating of perceived exertion (RPE) scale is a simple, reliable and valid tool to monitor exercise intensity through a wide variety of exercise types such as endurance (Foster et al., 1996) and resistance exercises (Gearhart JR et al., 2002).

Therefore, the aim of this study was to assess the acute effects of the sequence of concurrent high intensity resistance and repeated sprint endurance exercises on physiological (HR recovery), neuromuscular (jump height loss) and RPE parameters in recreational athletes.

METHODS

Subjects

Eighteen active men participated in this study (mean ± SD: 22.00 ± 2.00 years; 79.40 ± 9.87 kg and 175.62 ± 6.35 cm). Subjects were non-smokers, free from any pre-existing medical conditions and musculoskeletal injuries, they performed varied sport activities ("*gym*"-based training, endurance exercises such as running and swimming, and various sports such as soccer and basketball) and they were habitually exercising for >6h per week. Prior to the study, all subjects were informed about the testing protocols, possible risks involved and invited to provide written informed consent. The study was performed in accordance with the principles of the Declaration of Helsinki (October 2008, Seoul), and the experimental protocols were approved by the local ethics committee.

Experimental design

Subjects had previous experience in the training and testing employed in the study, and they were familiarized with protocols before data was collected. Subjects performed either endurance high-intensity session before the resistance session or reverse order. A 15-minute recovery period separated the training sessions. The training sessions were performed under control conditions (no strenuous activity 48h before). A period of at least 7 days separated the following training session, with an order of the exercises reversed (Figure 1). Both training sessions were conducted at the same time of the day for each individual in order to control for diurnal variation in hormone concentration. To examine the effects of exercise sequence on neuromuscular, cardiovascular, and perceptive parameters, the CMJ height and HR were recorded before each resistance and endurance exercise and 10s, 1min and 6min after. RPE was recorded at the end of the session (sRPE).

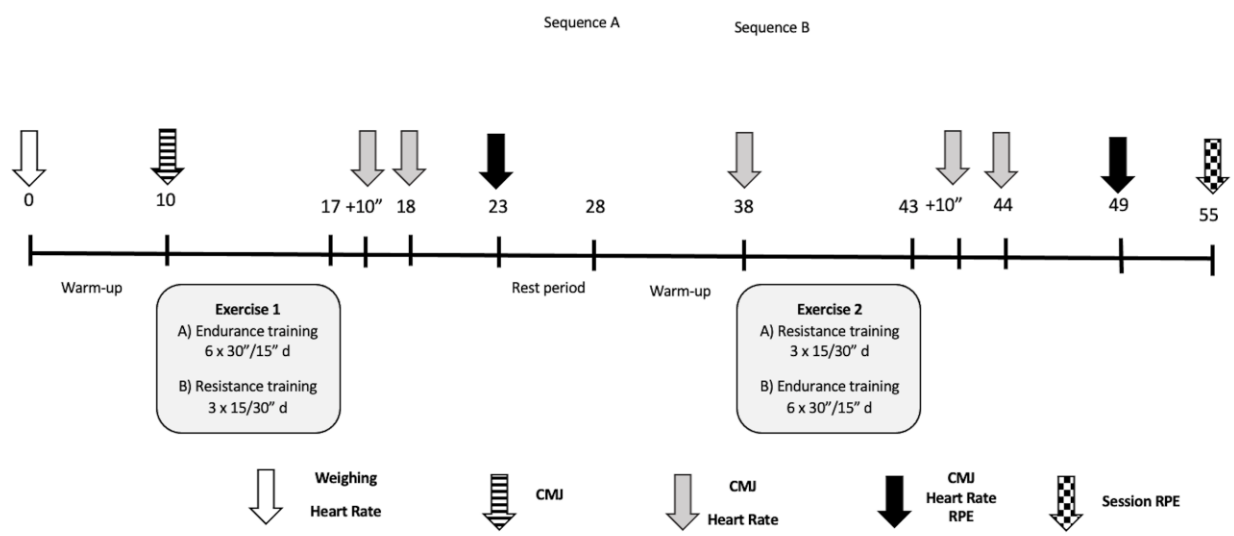


Figure 1. Overview of experimental design, indicating the training protocols and measurements.

Procedures

Repeated sprint endurance exercise

The repeated sprint endurance exercise protocol consisted of six 30-seconds “*all-out*” efforts performed in a cycle ergometer (Wattbike Ltd, Nottingham, UK) interspersed by 15-seconds of passive recovery. Moreover, they had a standardized countdown started at each effort and they were instructed to begin pedalling as fast as possible in each effort and trying to produce the highest power output possible. The repeated sprint endurance exercise was preceded by 10min of easy cycling as warm-up at 80-90 rpm.

Resistance exercise

The resistance exercise performed by the subjects consisted of 3 sets of 15 repetitions near failure of back squat exercise with rest intervals of 45s. Subjects were familiarized with the movement and warmed up prior to the training session. During training, the effort character (relationship between the repetitions realized and realizable) was used as a method of training control using repetitions in reserve, indicating to the subjects that they should have an intensity rating of RPE of 9 out of 10, i.e., 1 repetition in reserve (Zourdos et al., 2016). It was found that experienced and novice lifters may not possess equal abilities to perform a true one-repetition maximum (1RM) lift, and as a result, it may not be appropriate to use % of 1RM as a method to assign training load in all populations reserve (Zourdos et al., 2016). All subjects training ~ 70% loads of the previously known 1RM. Therefore, 3 sets of 15 repetitions (RIR 1, RPE 9) and rest intervals of 45s are a typical session targeting muscular endurance (Helms et al., 2016).

Before the resistance training, subjects performed a specific warm-up for the back squat exercise consisting of i) ankle, hip, thoracic spine, and shoulder mobility; ii) unloaded squats; iii) 4-5 incremental load sets to find the load corresponding to 15 repetitions [1 repetition in reserve]). The training was carried out using a 20 kg free bar, weight plates and a squatting rack (Eleiko Sport AB, Halmstad, Sweden). The squats were completed such that the anterior thighs were parallel to the ground before extending to a standing stance indicating by a researcher the moment where the thigh was parallel to the ground for each repetition. The training was designed and supervised by two resistance training specialists who checked that the proposed training was adhered to.

Testing
Subjects performed several CMJ using an optical measurement system (Optojump-next, Microgate, Bolzano, Italy) before, during and after of the endurance and resistance exercises. The CMJ starting position was a standing position with a straight torso and knees extended and subjects were asked to keep their hands on the hips throughout the jump. They were asked to jump for maximum height possible and jumping height were recorded. Subjects squatted from a standing stance to a knee angle of ~90° and immediately rebounded to jump as high as possible with feet shoulder width apart with their hands placed on their hips, i.e., jumping without the aid of the arms.

HR was recorded during the training session using a chest strap and HR monitor (H9, Polar Electro, Kempele, Finland). RPE was recorded at 1min post each exercise and the session RPE at 30min of the end.

Statistical analysis
SPSS 24.0 (SPSS Inc., Chicago, IL) was used for the analysis of the data. Normality and homogeneity of variance were determined with the Shapiro-Wilks and Levene tests, respectively. A repeated measures (time-pre, 10s, 1min and 6min) ANOVA was applied to analyse the difference in HR and CMJ between exercise modes (endurance vs resistance) in each sequence. A paired samples t-test was performed to analyse the difference in sRPE between sequences and RPE after each exercise mode in each sequence. The results are expressed as means and standard deviation (SD). The level of statistical significance was set at $p \leq .05$. Effect size was calculated using partial eta squared (partial η^2) or Cohen's d. All graphs and figures were created using GraphPad Prism (version 8.0.0 for Mac OS, GraphPad Software, San Diego, CA, USA).

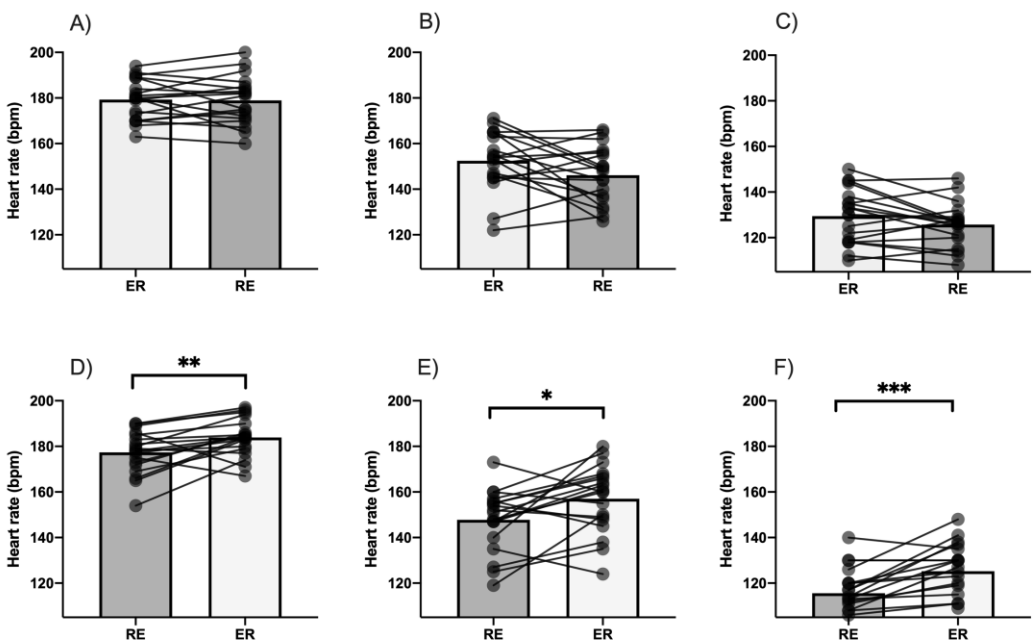
RESULTS

Results of the protocols on the CMJ, HR and sRPE are shown in the Table 1.

Significant protocol x time interactions were observed for HR ($p < .001$; partial $\eta^2 = 0.90$). There were no differences in HR between exercises mode in the sequence E-R at 10s, 1min and 6min after the exercise. However, in the sequence R-E, there were significant differences at 10s, 1min and 6min ($p < .05$), being higher after the endurance exercise compared to resistance exercise. In addition, both sequences started with a similar resting HR (69.68 ± 12.70 and 71.63 ± 11.30 bpm) (Figure 2).

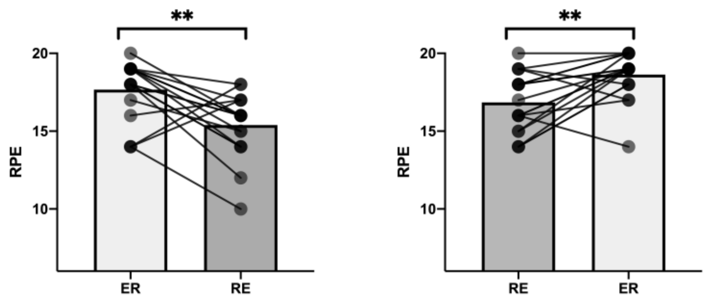
Table 1. Results of the exercise sequence on CMJ, heart rate, RPE and session RPE.

Variables	**Exercise sequence**			
		Endurance		
	Pre	Post 10s	Post 1min	Post 6min
CMJ (cm)	37.21 ± 5.99	26.62 ± 6.69	28.03 ± 8.00	31.41 ± 6.69
HR (bpm)	69.68 ± 12.70	179.31 ± 8.85	152.47 ± 13.09	129.47 ± 11.87
RPE (a.u.)			17.67 ± 1.91	
sRPE (a.u.)				
		Resistance		
	Pre	Post 10s	Post 1min	Post 6min
CMJ (cm)	37.12 ± 5.05	31.23 ± 5.87	33.52 ± 5.96	36.63 ± 6.06
HR (bpm)	121.74 ± 23.60	178.95 ± 10.50	146.10 ± 12.32	125.68 ± 9.59
RPE (a.u.)			15.39 ± 2.03	
sRPE (a.u.)				
		Resistance		
	Pre	Post 10s	Post 1min	Post 6min
CMJ (cm)	36.16 ± 5.62	31.40 ± 5.24	33.26 ± 5.65	35.97 ± 5.29
HR (bpm)	71.63 ± 11.30	177.37 ± 9.41	147.79 ± 13.46	115.58 ± 11.27
RPE (a.u.)			16.84 ± 1.89	
sRPE (a.u.)				
		Endurance		
	Pre	Post 10s	Post 1min	Post 6min
CMJ (cm)	37.11 ± 5.44	26.76 ± 5.77	28.39 ± 6.58	32.86 ± 5.89
HR (bpm)	113.31 ± 14.39	183.89 ± 8.25	157.00 ± 14.68	125.21 ± 12.33
RPE (a.u.)			18.63 ± 1.46	
sRPE (a.u.)				



*Note. *p ≤ .05, ** p ≤ .01; *** p ≤ .001.*

Figure 2. Individual values (lines) and average (columns) for heart rate post exercise of the sequence endurance-resistance at 10s (A), 1min (B) and 6min (C), and for the sequence resistance-endurance at 10s (D), 1min (E) and 6min (F).



Note. ** *p* ≤ *.01.*

Figure 3. Individual values (lines) and average (columns) for session RPE of the sequence endurance-resistance (A) and for the sequence resistance-endurance (B).

Significant protocol x time interactions were observed for sRPE (p < .01, Cohen's d = 0.60), being higher before the R-E sequence compared to E-R sequence (17.64 ± 1.28 a.u. and 16.53 ± 1.47 a.u.). RPE was significantly higher (p = .002, ES = 0.87) after endurance exercise compared to resistance exercise in the E-R sequence (17.67 ± 1.91 and 15.39 ± 2.03 a.u.) and in the R-E sequence (p = .002; ES = 0.84) (16.84 ± 1.89 and 18.63 ± 1.46 a.u.). There were no significant differences between the endurance exercises (p > .05; ES = 0.44). However, there were significant differences between the resistance exercises (p = .008; ES = 0.71) (Figure 3).

Finally, non-significant protocol x time interactions were observed for CMJ (partial η^2 = 0.31).

DISCUSSION

The aim of this study was to assess the acute effects of the sequence of concurrent high-intensity resistance and endurance exercises on physiological, neuromuscular, and perceptive parameters in recreational athletes.

The main finding of this study was that there was no influence of exercise sequence on neuromuscular parameters. However, the HR was significantly higher post endurance exercise in the R-E sequence compared to the resistance exercise, while no differences were observed in the E-R sequence. In addition, the subjects perceived as a harder session the R-E sequence, being also harder the endurance exercise in that sequence.

From a resistance exercise acute effects standpoint, previous studies have shown that greater training load-volume (Abboud et al., 2013), sets performed to failure (Morán-Navarro et al., 2017) or a combination of multiple exercises performed in one set (Weakley et al., 2017) induce greater physiological strain for at least 24h post-exercise. In addition, greater resistance training intensities (≥80% of 1RM) induce greater stress than light-load (Draganidis et al., 2013; Hasenoehrl et al., 2016) and it could impair the subsequent exercise. Therefore, it seems reasonable consider several factors when a CT is designed and the effects on the subsequent exercises. In our case, the training volume was low (45 repetitions), intensities about 70% of 1RM, near to failure (1 repetition in reserve) and only 45s of recovery between sets.

As our results show, the R-E sequence had a higher cardiovascular stress (higher HR post exercise) and the effort perception of the subjects was more elevated after the endurance exercise, thus, the previous exercise should have influenced. Previous studies have reported that a single resistance training bout impairs the subsequent endurance performance even in a period of 24-72h after (Burt & Twist, 2011; Doncaster & Twist, 2012). It is necessary to mention that the endurance exercise performed in our study was a high intensity effort (repeated cycling sprints of 30s) with a short recovery period (15s), therefore, the muscle fibres recruited were predominantly fast twitch. Some authors have speculated that the acute effects of resistance training may have greater deleterious effects on high intensity endurance activities, due to the fast twitch muscle fibres have greater susceptibility to muscle damage and glycogen depletion (Connolly et al., 2003), and predominantly recruited at intensities above the anaerobic threshold (Abernethy et al., 1990). However, we did not found differences in the jump height loss (as neuromuscular measure) during both sequence of training.

In relation to the recovery between exercise modes, our study had a passive recovery of 5min and a specific active warm-up of 10min previous the second exercise of the session. This short recovery period could have influence on the subsequent endurance or resistance exercise (according to the sequence). Robineau et al. (Robineau et al., 2016) compared the effects of R-E sequence on the same day, 6h and 24h before. These authors suggested an interference effect on endurance development for groups that undertook R-E sequence on the same day. Thus, the recovery period between exercise modes would be another factor to consider when concurrent training is prescribed in the same day. In our case, only 15min of recovery period (passive and active) could be insufficient and increase cardiovascular stress in the R-E sequence compared to E-R sequence. For example, a previous study shows that the type of warm-up (active/passive) does not seem to affect the subsequent high-intensity exercise performance (Gray & Nimmo, 2001).

Previous studies have found a considerable impact of neuromuscular fatigue in response to resistance exercise mode (Bird et al., 2013; Häkkinen et al., 1988; Stock et al., 2010) for up to 72h post-exercise. Nájera-Ferrer et al. (Nájera-Ferrer et al., 2021) found higher reductions in CMJ height along with elevated blood lactate concentration, following a R-E sequence but not in the E-R sequence. These authors suggested that high-fatigue resistance exercise before endurance exercise should be avoided to prevent the quality of the subsequent endurance exercise. However, in our case, both exercise modes in both sequences had a similar neuromuscular fatigue and does not appear to have influenced on the subsequent exercise.

Regarding the sRPE, previous study showed that this variable was not affected by the duration of the exercise session (Green et al., 2009), thus, the intensity of exercise seems to be key in the subjective ratings of effort. Di Blasio et al. (Di Blasio et al., 2012) compared three concurrent protocols on acute effects of objective and subjective variables. They found that the lowest increase in the energy expenditure, VO_2 and lowest decrease of proportion of oxygen in the expired air (FeO_2) were coupled with the lowest increase of the perceived exertion in the E-R sequence compared to R-E sequence. Therefore, the order of exercise affected both objective and subjective variables, due to the relationship between RPE and objective variables, such as HR and VO_2. Another reason why the sRPE was higher after the R-E sequence in our study could be that the subjects perceived the endurance exercise mode as more demanding, and the timing of that exercise (at the final of the session) could affect the overall session perception. In this way, Kilpatrick et al. (Kilpatrick et al., 2009) reported that sRPE was affected by the perceived intensity taken during the final part of a running session.

CONCLUSION

In conclusion, our results suggest that the order of exercises during CT affects to the second exercise when performed in a R-E sequence, with a more cardiovascular stress and higher sRPE. Therefore, it is important to combine several variables (intensity and recovery between exercises, mainly) in a proper way to obtain a better result during a CT program. Finally, we recommend avoiding the R-E sequence in endurance athletes to not impair the endurance performance or quality of endurance session.

AUTHOR CONTRIBUTIONS

Conception: Fernando González-Mohíno and Victor Rodrigo-Carranza. Performance of work: Fernando González-Mohíno and Victor Rodrigo-Carranza. Interpretation or analysis of data: Fernando González-Mohíno, Daniel Juárez Santos-García and José María González-Ravé. Preparation of the manuscript: Fernando González-Mohíno, Victor Rodrigo-Carranza Daniel Juárez Santos-García. Revision for important intellectual content: All authors. Supervision: Daniel Juárez Santos-García and José María González-Ravé.

SUPPORTING AGENCIES

No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

ETHICAL CONSIDERATIONS

All subjects gave written informed consent after a detailed description of the study procedures. The study was approved by the local Ethics Committee of the University (FGM02102019) and was conducted in accordance with the Declaration of Helsinki.

REFERENCES

Abboud, G. J., Greer, B. K., Campbell, S. C., & Panton, L. B. (2013). Effects of load-volume on EPOC after acute bouts of resistance training in resistance-trained men. The Journal of Strength & Conditioning Research, 27(7), 1936-1941. https://doi.org/10.1519/JSC.0b013e3182772eed

Abernethy, P. J., Thayer, R., & Taylor, A. W. (1990). Acute and chronic responses of skeletal muscle to endurance and sprint exercise. Sports medicine, 10(6), 365-389. https://doi.org/10.2165/00007256-199010060-00004

Bird, S. P., Mabon, T., Pryde, M., Feebrey, S., & Cannon, J. (2013). Triphasic multinutrient supplementation during acute resistance exercise improves session volume load and reduces muscle damage in strength-trained athletes. Nutrition research, 33(5), 376-387. https://doi.org/10.1016/j.nutres.2013.03.002

Borresen, J., & Lambert, M. I. (2008). Autonomic control of heart rate during and after exercise. Sports medicine, 38(8), 633-646. https://doi.org/10.2165/00007256-200838080-00002

Burt, D. G., & Twist, C. (2011). The effects of exercise-induced muscle damage on cycling time-trial performance. The Journal of Strength & Conditioning Research, 25(8), 2185-2192. https://doi.org/10.1519/JSC.0b013e3181e86148

Coffey, V. G., Jemiolo, B., Edge, J., Garnham, A. P., Trappe, S. W., & Hawley, J. A. (2009). Effect of consecutive repeated sprint and resistance exercise bouts on acute adaptive responses in human skeletal muscle. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 297(5), R1441-R1451. https://doi.org/10.1152/ajpregu.00351.2009

Connolly, D. A., Sayers, S. P., & McHugh, M. P. (2003). Treatment and prevention of delayed onset muscle soreness. Journal of strength and conditioning research, 17(1), 197-208. https://doi.org/10.1519/00124278-200302000-00030

Di Blasio, A., Gemello, E., Di Iorio, A., Di Giacinto, G., Celso, T., Di Renzo, D., Sablone, A., & Ripari, P. (2012). Order effects of concurrent endurance and resistance training on post-exercise response of non-trained women. Journal of sports science & medicine, 11(3), 393.

Doncaster, G. G., & Twist, C. (2012). Exercise-induced muscle damage from bench press exercise impairs arm cranking endurance performance. European journal of applied physiology, 112(12), 4135-4142. https://doi.org/10.1007/s00421-012-2404-y

Draganidis, D., Chatzinikolaou, A., Jamurtas, A. Z., Carlos Barbero, J., Tsoukas, D., Theodorou, A. S., Margonis, K., Michailidis, Y., Avloniti, A., & Theodorou, A. (2013). The time-frame of acute resistance exercise effects on football skill performance: The impact of exercise intensity. Journal of sports sciences, 31(7), 714-722. https://doi.org/10.1080/02640414.2012.746725

Eddens, L., van Someren, K., & Howatson, G. (2018). The role of intra-session exercise sequence in the interference effect: a systematic review with meta-analysis. Sports medicine, 48(1), 177-188. https://doi.org/10.1007/s40279-017-0784-1

Foster, C., Daines, E., Hector, L., Snyder, A. C., & Welsh, R. (1996). Athletic performance in relation to training load. Wisconsin medical journal, 95(6), 370-374.

Fry, R. W., Morton, A. R., & Keast, D. (1992). Periodisation of training stress--a review. Canadian journal of sport sciences = Journal canadien des sciences du sport, 17(3), 234-240.

Gearhart JR, R. E., Goss, F. L., Lagally, K. M., Jakicic, J. M., Gallagher, J., Gallagher, K. I., & Robertson, R. J. (2002). Ratings of perceived exertion in active muscle during high-intensity and low-intensity resistance exercise. The Journal of Strength & Conditioning Research, 16(1), 87-91. https://doi.org/10.1519/00124278-200202000-00013

Gray, S., & Nimmo, M. (2001). Effects of active, passive or no warm-up on metabolism and performance during high-intensity exercise. Journal of sports sciences, 19(9), 693-700. https://doi.org/10.1080/02640410152475829

Green, J. M., McIntosh, J. R., Hornsby, J., Timme, L., Gover, L., & Mayes, J. L. (2009). Effect of exercise duration on session RPE at an individualized constant workload. European journal of applied physiology, 107(5), 501-507. https://doi.org/10.1007/s00421-009-1153-z

Häkkinen, K., Pakarinen, A., Alen, M., Kauhanen, H., & Komi, P. (1988). Daily hormonal and neuromuscular responses to intensive strength training in 1 week. International Journal of Sports Medicine, 9(06), 422-428. https://doi.org/10.1055/s-2007-1025044

Hasenoehrl, T., Wessner, B., Tschan, H., Vidotto, C., Crevenna, R., & Csapo, R. (2016). Eccentric resistance training intensity may affect the severity of exercise induced muscle damage. The Journal of sports medicine and physical fitness, 57(9), 1195-1204. https://doi.org/10.23736/S0022-4707.16.06476-8

Helms, E. R., Cronin, J., Storey, A., & Zourdos, M. C. (2016). Application of the repetitions in reserve-based rating of perceived exertion scale for resistance training. Strength and conditioning journal, 38(4), 42. https://doi.org/10.1519/SSC.0000000000000218

Hickson, R. C. (1980). Interference of strength development by simultaneously training for strength and endurance. European journal of applied physiology and occupational physiology, 45(2), 255-263. https://doi.org/10.1007/BF00421333

Jimenez-Reyes, P., Pareja-Blanco, F., Cuadrado-Peñafiel, V., Morcillo, J., Párraga, J., & González-Badillo, J. (2016). Mechanical, metabolic and perceptual response during sprint training. International Journal of Sports Medicine, 37(10), 807-812. https://doi.org/10.1055/s-0042-107251

Jones, T. W., Howatson, G., Russell, M., & French, D. N. (2017). Effects of strength and endurance exercise order on endocrine responses to concurrent training. European journal of sport science, 17(3), 326-334. https://doi.org/10.1080/17461391.2016.1236148
Kannankeril, P. J., Le, F. K., Kadish, A. H., & Goldberger, J. J. (2004). Parasympathetic effects on heart rate recovery after exercise. Journal of investigative medicine, 52(6), 394-401. https://doi.org/10.1177/108155890405200634
Kilpatrick, M. W., Robertson, R. J., Powers, J. M., Mears, J. L., & Ferrer, N. F. (2009). Comparisons of RPE before, during, and after self-regulated aerobic exercise. Medicine & Science in Sports & Exercise, 41(3), 682-687. https://doi.org/10.1249/MSS.0b013e31818a0f09
Leveritt, M., & Abernethy, P. (1999). Acute effects of high-intensity endurance exercise on subsequent resistance activity. The Journal of Strength & Conditioning Research, 13(1), 47-51. https://doi.org/10.1519/00124278-199902000-00009
Morán-Navarro, R., Pérez, C. E., Mora-Rodríguez, R., de la Cruz-Sánchez, E., González-Badillo, J. J., Sanchez-Medina, L., & Pallarés, J. G. (2017). Time course of recovery following resistance training leading or not to failure. European journal of applied physiology, 117(12), 2387-2399. https://doi.org/10.1007/s00421-017-3725-7
Nájera-Ferrer, P., Pérez-Caballero, C., González-Badillo, J. J., & Pareja-Blanco, F. (2021). Effects of Exercise Sequence and Velocity Loss Threshold During Resistance Training on Following Endurance and Strength Performance During Concurrent Training. International journal of sports physiology and performance, 16(6), 811-817. https://doi.org/10.1123/ijspp.2020-0483
Robineau, J., Babault, N., Piscione, J., Lacome, M., & Bigard, A. X. (2016). Specific training effects of concurrent aerobic and strength exercises depend on recovery duration. The Journal of Strength & Conditioning Research, 30(3), 672-683. https://doi.org/10.1519/JSC.0000000000000798
Sanchez-Medina, L., & González-Badillo, J. J. (2011). Velocity loss as an indicator of neuromuscular fatigue during resistance training. Medicine and science in sports and exercise, 43(9), 1725-1734. https://doi.org/10.1249/MSS.0b013e318213f880
Shetler, K., Marcus, R., Froelicher, V. F., Vora, S., Kalisetti, D., Prakash, M., Do, D., & Myers, J. (2001). Heart rate recovery: validation and methodologic issues. Journal of the American College of Cardiology, 38(7), 1980-1987. https://doi.org/10.1016/S0735-1097(01)01652-7
Stock, M. S., Young, J. C., Golding, L. A., Kruskall, L. J., Tandy, R. D., Conway-Klaassen, J. M., & Beck, T. W. (2010). The effects of adding leucine to pre and postexercise carbohydrate beverages on acute muscle recovery from resistance training. The Journal of Strength & Conditioning Research, 24(8), 2211-2219. https://doi.org/10.1519/JSC.0b013e3181dc3a10
Weakley, J. J., Till, K., Read, D. B., Roe, G. A., Darrall-Jones, J., Phibbs, P. J., & Jones, B. (2017). The effects of traditional, superset, and tri-set resistance training structures on perceived intensity and physiological responses. European journal of applied physiology, 117(9), 1877-1889. https://doi.org/10.1007/s00421-017-3680-3
Zourdos, M. C., Klemp, A., Dolan, C., Quiles, J. M., Schau, K. A., Jo, E., Helms, E., Esgro, B., Duncan, S., & Merino, S. G. (2016). Novel resistance training-specific rating of perceived exertion scale measuring repetitions in reserve. The Journal of Strength & Conditioning Research, 30(1), 267-275. https://doi.org/10.1519/JSC.0000000000001049