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ACUTE EFFECT OF TIME-EFFICIENT INTERMITTENT AND HIGH-INTENSITY CONTINUOUS PROTOCOLS ON HALF-SQUAT PERFORMANCE

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ABSTRACT

Purpose: To analyze the acute effect a short high intensity interval training (HIIT) protocol or a longer high-intensity continuous running protocol upon subsequent resistance exercise performance in young women. Materials and Methods: Fifteen physically active healthy women (24±5 years) performed three randomized experimental sessions, with a minimum of a 48-hour rest period between them. Participants performed three sets of half-squat at 80% of one repetition maximum to volitional failure, preceded by a) a HIIT protocol (8 x 40s sprints at the velocity corresponding to maximal oxygen uptake); b) a 20-min continuous protocol (at heart rate corresponding to second ventilatory threshold); or c) a control condition with no previous endurance exercise. The maximum number of half-squat repetitions were recorded, and results were analyzed with repeated measures analysis of variance, with Bonferroni post-hoc test. Results: A progressive reduction in the number of half-squat repetitions was observed across the HIIT protocol (p<0.001) in comparison to the control session. A reduction in the number of repetitions in the continuous protocol was observed only in the first and second sets (p=0.037). The total work was greater in the control (26.0±8.4 repetitions) protocol in comparison to the continuous (19.7±7.1 repetitions) and HIIT (17.7±6.6 repetitions) protocols (p<0.001). Conclusion: Continuous or high-intensity interval running before strength training may compromise half-squat performance with the same load, suggesting that both affect the quality of subsequent lower limb exercise.

Key words: Muscle strength. Fatigue. Physical functional performance.

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RESUMO

Efeito agudo de protocolos intermitentes e contínuos de alta intensidade com eficiência de tempo no desempenho do meio agachamento

Objetivo: Analisar o efeito agudo de um protocolo curto de treinamento intervalado de alta intensidade (HIIT) ou de um protocolo longo de corrida contínua de alta intensidade sobre o desempenho subsequente de exercícios de força em mulheres jovens. Materiais e Métodos: Quinze mulheres saudáveis fisicamente ativas (24±5 anos) realizaram três sessões experimentais randomizadas, com um período de descanso de 48 horas entre elas. As participantes realizaram três séries de meio agachamento a 80% de uma repetição máxima até a falha voluntária, precedidas por a) um protocolo HIIT (8 sprints de 40s na velocidade correspondente ao consumo máximo de oxigênio); b) um protocolo contínuo de 20 minutos (na frequência cardíaca correspondente ao segundo limiar ventilatório); ou c) uma condição de controle sem exercício de corrida prévio. O número máximo de repetições do meio agachamento foi registrado e os resultados foram analisados por análise de variância com medidas repetidas e teste post-hoc de Bonferroni. Resultados: Em comparação com o controle, uma redução progressiva no número de repetições do meio agachamento foi observada em todo o protocolo HIIT (p<0,001). A redução no número de repetições no protocolo contínuo foi observada apenas na primeira e segunda séries (p=0,037). O volume total foi maior no protocolo controle (26,0±8,4 repetições) comparado aos protocolos contínuo (19,7±7,1 repetições) e HIIT (17,7±6,6 repetições) (p<0,001). Conclusão: A corrida contínua ou intervalada de alta intensidade antes do treino de força pode comprometer o desempenho do meio agachamento com a mesma carga, sugerindo que ambas afetam a qualidade do exercício subsequente dos membros inferiores.

Palavras-chave: Força muscular. Fadiga. Desempenho físico funcional.

INTRODUCTION

Concurrent training consists of performing strength and endurance exercises in the same or different exercise sessions (Schumann et al., 2015), and it is commonly employed as a training mode in the context of both health and high-performance sports.

The acute hypothesis related to the interference effect suggests that the volume of each strength exercise session in concurrent training may be reduced due to residual fatigue from the previous aerobic exercise, potentially leading to chronic impairment in the strength gains (Craig et al., 1991; Leveritt et al., 1999).

If this hypothesis is correct, one may speculate that the type and intensity of the preceding endurance exercise may relate to the magnitude of impairment in strength performance.

Previous studies have analyzed the acute effect of performing intermittent endurance protocols on subsequent strength performance, especially in young men (Andrade et al., 2021; Andrade et al., 2022; Souza et al., 2007; Leveritt, Abernethy, 1999; Panissa et al., 2015; Panissa et al., 2012; Sporer, Wenger, 2003), and generally demonstrate that the number of repetitions in lower limb resistance exercises is reduced after a variety of intermittent protocols.

According to Souza et al., (2007), an endurance intermittent exercise performed at intensity relative to the velocity of maximal oxygen uptake (VO_{2max}) brings about a greater reduction in resistance exercise performance (i.e., leg press) when compared to a continuous session at 90% of the velocity at anaerobic threshold.

The magnitude of this acute effect on strength may depend on a number of variables, including the muscle group involved in both exercise modalities (Andrade et al., 2022; Souza et al., 2007; Leveritt et al., 1999; Leveritt, Abernethy, 1999), interval duration between the endurance and strength exercises (Panissa et al., 2012; Sporer, Wenger, 2003), and the intensity of both exercise modes (Souza et al., 2007; Docherty, Sporer, 2000).

A growing number of studies about high-intensity interval training (HIIT - performance of a sequence of stimuli at submaximal to supramaximal intensity, followed by passive or active rest periods (Buchheit, Laursen, 2013) and the increased application of this type of protocol at gym and fitness centers, have made its use as a training routine widespread (Milanovic et al., 2015).

Since “lack of time” is frequently reported as a barrier to exercise by the adult population (Reichert et al., 2007; Sebastião et al., 2013) and considering the high prevalence of sedentarism (Mielke et al., 2014), time-efficient exercise protocols may work as an alternative to reduce this barrier.

Although previous studies (Andrade et al., 2021; Andrade et al., 2022; Panissa et al., 2012; Sporer, Wenger, 2003) have analyzed the effects of HIIT sessions on subsequent strength performance, to the best of the authors’ knowledge no study has investigated the influence of a time-efficient intermittent protocol compared to a continuous protocol on half-squat resistance exercise.

Accordingly, the purpose of the present study was to analyze the acute effect of performing a prior short 2:1 HIIT protocol or a longer high-intensity continuous protocol on subsequent half-squat performance in young women.

MATERIALS AND METHODS

Participants

Fifteen healthy young women from 18 to 35 years old, with previous strength training experience, volunteered to participate in the current study.

Exclusion criteria included tobbaco use, and a history of neuromuscular, metabolic, endocrine, and cardiorespiratory diseases.

Subjects were not taking any medications that are known to influence cardiorespiratory and neuromuscular performance and were advised not to change their nutritional practices throughout the study period.

Each participant read and signed an informed consent term, which described the study risks and procedures.

The study was previously approved by the Ethics Research Committee of the Federal University of Pelotas (registration number 48474315.4.0000.5313).

Procedures

Participants visited the laboratory in six separate sessions to: 1) a familiarization session and body composition measurements; 2) determination of one maximum repetition

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(1RM) in the half-squat exercise, 3) perform a running maximal incremental test to determine participants' individual endurance exercise workloadsand; 4) three randomized protocol sessions, with a minimum of a 48-h rest between all the sessions.

In the first session, participants' body mass and height were measured using a digital scale and stadiometer (Filizola, São Paulo, Brazil).

Participants were then familiarized with testing procedures, including commands for each test, the half-squat exercise, and equipment for the maximal incremental test (treadmill, mask, and gas analyzer). Participants performed 12 to 15 repetitions in two to three sets of half-squat.

In the following session, the load corresponding to the 1RM in the half-squat exercise was determined. To this end, participants performed a 5-minute general warm-up in a cycle ergometer and a specific warm-up in the half-squat exercise with 50% of the predicted 1RM load. The initial 1RM testing load was predicted based on participants' body mass, and each subject performed the maximal number of repetitions (up to a maximum of 10) in each trial.

When more than one repetition could be completed, the new testing load was adjusted according to Lombardi's equation (Lombardi, 1989) for the following trial.

A maximum of five attempts were performed, with 4 min of rest interval between each trial.

The half-squat movement cadence was controlled with the assistance of a digital metronome (MA-30, KORG, Japan), so that each repetition was completed in 4 s (2 s for concentric phase, and 2 s for eccentric phase).

The half-squat 1RM was then defined as the highest load the participant could lift within the determined range of motion (thigh parallel to the ground) and movement cadence.

The maximal incremental test was performed using a treadmill (Arktus, Santa Tereza do Oeste, Brazil) to determine the heart rate (HR) equivalent to the second ventilatory threshold and the velocity corresponding to the VO_{2max} (vVO_{2max}). The test started at 6 $km.h^{-1}$ during 2 min and velocity was increased progressively at 1 $km.h^{-1}$ each minute until exhaustion. The test was finished when the participant indicated exhaustion. Respiratory gases were collected using a mixing-box-type portable gas analyzer (VO2000; MedGraphics, USA), previously calibrated according to the manufacturer's specifications.

The sampling rate was set at 1 for every 3 breaths, and data was analysed with the Aerograph software (MedGraphics, USA). During the incremental test, HR was recorded every 30 s (FS1, Polar, Kempele, Finland), and the test was considered maximal when at least two of the following criteria were met: predicted maximal heart rate was reached (220-age), a respiratory exchange ratio greater than 1.15 was observed or a maximal respiratory rate of at least 35 breaths per minute (Howley et al., 1995).

The second ventilatory threshold was determined using the ventilation-workload slope and was confirmed through the slope of the ventilatory equivalent of VO_2 (V_E/VO_2) and VCO_2 (V_E/VCO_2) (Wasserman, 1988). Blinded analysis was performed by two independent researchers, and in case of disagreement, a third researcher was assessed to define the point referent to the second ventilatory threshold (Hug et al., 2004).

After the initial visits, participants returned to the laboratory in three additional occasions for the main experimental sessions. In the control protocol participants performed three sets of half-squat, completing the maximal number per set at 80% of 1RM, with 2 min of interval between them. A warm-up of 5 minutes was performed on the treadmill at 6 $km.h^{-1}$. Two minutes after warming-up participants performed half-squat protocol, with each set performed until failure, defined the point when the participant demonstrated 1) inability to complete an entire repetition, 2) the repetition when the stipulated full range of motion could no longer be sustained; or 3) when the exercise could no longer be performed at the pre-stipulated cadence - (i.e. 2 s by contraction phase) (Conceição et al., 2014).

In the intermittent protocol session, the HIIT protocol was performed on treadmill prior to the half-squat protocol. The same 5-minute warm-up was performed and after 1minute participants performed 8 sprints of 40 s at 100% vVO_{2max}, with 20 s of passive rest (i.e. 2:1 exercise to rest ratio). After 2-minute passive rest interval, the participants completed the half-squat protocol.

For the continuous protocol, a prior walking and/or running continuous exercise was performed, so that after the initial warm-up participants performed a 20 minute exercise bout on the treadmill at ± 5 bpm of HR

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equivalent to their second ventilatory threshold (HR_{VT2}), followed by the half-squat exercise session.

In all protocols the number of completed repetitions in each set were registered. Total work was calculated based on the product of total number of repetitions and load.

Data Analysis

Results are reported as mean ± SD. Data normality was verified by the Shapiro-Wilk test. A two-way ANOVA with Bonferroni adjustment was used to compare the protocol and set effects in the number of repetitions. In order to compare the total number of repetitions and total load between protocols, a repeated measures ANOVA was used, with Bonferroni post hoc whenever necessary. In addition, the partial η^2 was also identified to estimate the effect size for the comparison among exercises. Reference values for the interpretation of the effect size correspond to 0.02 for small, 0.13 for medium, and 0.26 for large. The significance level adopted in this study was α = 0.05. All statistical tests were performed in the SPSS vs. 20.0.

RESULTS

Table 1 presents the anthropometric data and physical fitness parameters from the participants.

Table 1 - Participants' characteristics.

Variables	Mean ± SD
Age (years)	24.2 ± 4.6
Body mass (kg)	58.9 ± 5.5
Height (cm)	161.5 ± 5.4
1RM (kg)	61.6 ± 9.8
HR_{max} (bpm)	195.8 ± 10.1
HR_{VT2} (bpm)	183.1 ± 9.3
VO_{2max} ($ml.kg^{-1}.min^{-1}$)	49.4 ± 5.9
vVO_{2max} ($km.h^{-1}$)	12.4 ± 1.5

Note: 1RM, half-squat one repetition maximum; HR_{max}, maximal heart rate; HR_{VT2}, heart rate at second the ventilatory threshold; VO_{2max}, maximal oxygen uptake; vVO_{2max}, maximal velocity of VO_{2max}

The number of repetitions between protocols and sets is presented in Table 2. A significant set*protocol interaction was observed, revealing a distinct pattern of change in completed repetitions throughout each protocol (p=0.014).

Regarding protocols comparison, a significant reduction in the number of half-squat repetitions was verified for the HIIT protocol at all sets, while a significant reduction was observed only in the first and second sets for the continuous protocol, both in comparison to the control session. No differences between the HIIT and continuous protocols were observed at all sets. Regarding sets comparison, the HIIT protocol resulted in no significant reduction across the sets. On the other hand, the continuous protocol revealed a significant reduction from the first to the third set, while the control session resulted in a significant progressive impairment across the sets.

The total number of repetitions and total work performed in the half-squat exercise in each condition are presented in Figure 1.

The sum of repetitions completed for the same absolute load (and thus the total work) was greater in the control (26.0 ± 8.4 repetitions) protocol in comparison to the continuous (19.7 ± 7.1 repetitions) and HIIT (17.7 ± 6.6 repetitions) protocols (p<0.001), with no difference in the resistance exercise volume between the continuous and HIIT protocols.

Table 2 - Number of maximal repetitions performed in the half-squat exercise in control, continuous and high intensity interval training protocols (mean ± SD).

	Control (Rep)	Continuous (Rep)	HIIT (rep)	Protocol effect	Set effect	Interaction
SET 1	10.7 ± 3.8[a*]	7.4 ± 2.9[a]	6.1 ± 3.3[a]	p<0.001 η_p^2=0.514	p<0.001 η_p^2=0.595	p=0.014 η_p^2=0.252
SET 2	8.1 ± 2.3[b*]	6.3 ± 2.7[ab]	6.1 ± 1.8[a]			
SET 3	7.2 ± 2.8[c#]	6.1 ± 1.9[b]	5.4 ± 2.6[a]			

Note: Rep = repetitions; HIIT = high intensity interval training. *significant difference between control and other protocols; #significant difference between control and HIIT protocol; Different letters indicate significant difference between sets

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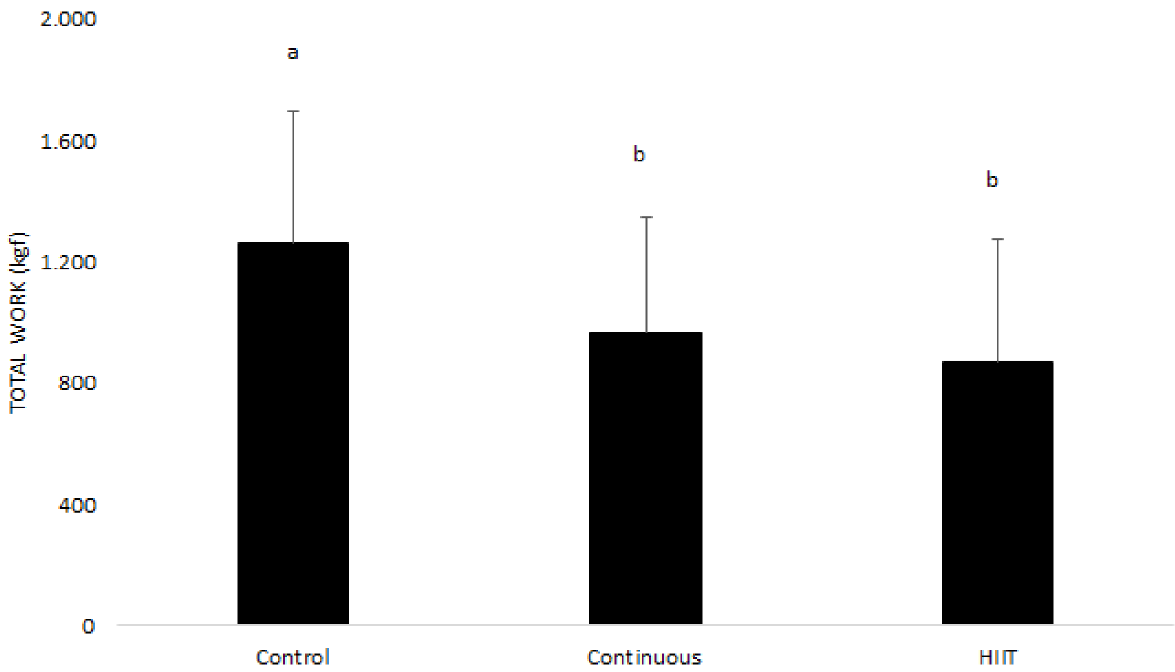

Figure 1 - Half-squat total work in the control, continuous and high intensity interval training (HIIT) protocols. Different letters represent significant difference ($p<0.05$).

DISCUSSION

The main finding of this study was that both continuous and HIIT exercise protocols led to similar impairment in subsequent performance lower limb strength exercise performance, as evidenced by the decrease in the total number of repetitions completed in the half-squat exercise compared to the control condition.

Regarding each endurance exercise protocol, the HIIT protocol resulted in an acute reduction in the number of half-squat repetitions across all three sets. In contrast, the continuous protocol only impaired strength exercise performance during the first and second sets compared to the control condition. Nevertheless, no significant difference was observed between the HIIT and continuous protocols in the total number of repetitions performed in the whole strength exercise sessions.

The present study sought to investigate the acute hypothesis in different endurance protocols performed prior to a strength exercise session. The acute hypothesis states that an impairment in chronic strength gains during concurrent training results from a lower strength training volume and quality due to the fatigue caused by the aerobic exercise previously performed (Craig et al., 1991; Leveritt et al., 1999), as observed in the present study. In fact, some studies have observed impaired concurrent training-induced strength gains in older adults when endurance exercise preceded strength exercise in comparison to opposite concurrent exercise sequences (Cadore et al., 2012; Pinto et al., 2015).

On the other hand, some studies have reported no difference in strength adaptations to either concurrent training exercise sequence in young and older adults (Chtara et al., 2008; Schumann et al., 2015; Wilhelm et al., 2014), suggesting that several confounding factors factors possibly influences the acute hypothesis.

Results from the present study have shown a decrease in the strength performance in three sets of a squat exercise at 80% of 1RM after a treadmill high- intensity interval exercise session (8 x 40s:20s at 100% vVO_{2max}), in agreement with Leveritt and Abernethy (1999) and Andrade et al., (2022).

Leveritt and Abernethy (1999) investigated the effect of five 5-minute bouts of high-intensity exercise on a cycle ergometer (1 min at 40%, 1min at 60%, 1min at 80%, and 2 min at 100% of VO_{2peak}, with 5-minute passive rest interval) on the number of maximal repetitions on half-squat exercise at 80% of

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1RM. More recently, Andrade et al., (2022) applied the same HIIT protocol as the present study (8 x 40s:20s at 100% vVO_{2max}) but with young men as participants. A significantly lower number of repetitions for the same load was performed after the high-intensity endurance protocols in both studies.

Accordingly, Panissa et al., (2015) also observed acute interference in the strength exercise after a treadmill and a cycle ergometer HIIT protocol.

The maximal number of repetitions and the total volume performed were significantly lower in the first set after both HIIT sessions when compared with the control condition (6 ± 3 repetitions for the treadmill, 4 ± 5 repetitions for the cycle ergometer, and 10 ± 4 repetitions for the control), with further impairment in the repetitions completed in the second set after the cycle ergometer HIIT protocol (5 ± 4 repetitions for cycle ergometer and 7 ± 5 repetitions for control).

Such results are partially in agreement with the present findings, and differences related to ergometer and interval protocol between studies may be due to the distinct endurance exercise bout duration and rest interval on treadmill protocols (the present study found differences between HIIT and control protocols throughout the three sets of strength exercise).

Despite the lower duration of effort in the present study (40 s) in comparison to Panissa et al., (2015) (1 minute), the different effort: rest interval ratio (2:1 versus 1:1, respectively) may have resulted in higher fatigue in the present study and, thus, greater impairment in squat exercise performance.

Previous studies have explored the impact of the type of endurance exercise (i.e., continuous vs interval) on lower limb performance.

Sporer and Wenger (2003) compared two endurance exercise sessions on a cycle ergometer: intermittent (6 x 3 minutes: 3 minutes at 85 - 100% of maximal aerobic power) and continuous (36 minutes at 70% of maximal aerobic power), followed by four sets of leg press and bench press at 75% of 1RM with recovery ranging from 4 to 24-h after the endurance exercise.

Leg press strength performance was impaired even with 8-h of recovery after the endurance protocols, without significant difference between types of endurance exercise training. In the present study, we employed a shorter recovery interval between the endurance and the strength sessions (i.e. 5 minutes between the treadmill exercise and the strength exercise session) to simulate a typical training session in non-athletic settings (e.g., gyms and fitness training centers) and our findings are in accordance to Sporer and Wenger (2003).

In a more similar study, Souza et al., (2007) analyzed two endurance treadmill protocols (5 km continuous at 90% of anaerobic threshold velocity and 5 km intermittent 1min:1min 100% vVO_{2max}) on the number of repetitions in leg press and bench press exercises and reported an impairment in strength exercise performance only after the high-intensity interval session.

Such differences may be due to the intensities used during the continuous protocols since Souza et al., (2007) employed a continuous at 90% velocity of the anaerobic threshold, whereas the current continuous exercise was performed at 100% of the HR of anaerobic threshold.

These differences in the intensity of training may have led to distinct physiological stress and adjustments (central or peripheral) (Docherty, Sporer, 2000).

For example, according to the concurrent training interference zone hypothesis proposed by Docherty and Sporer (2000), the continuous exercise employed in this study may not be characterized to have either a complete central or a complete peripheral neuromuscular impact.

Notwithstanding, the proposal of interference zone from Docherty and Sporer (2000) is not well consolidated in the literature and more studies are necessary to investigate and confirm this hypothesis.

The present study has some limitations. For example, the lack of central and peripheral measures of muscular fatigue limits the analysis of the site of fatigue after each endurance protocol.

In addition, the assessment of additional measures of muscular strength (e.g. maximal strength, endurance, etc) would be useful in explaining the acute effect of endurance exercise on different strength exercise conditions.

Therefore, future studies should investigate different interval protocols (different work: rest ratios and ergometers) and explore higher strength exercise volume (greater number of sets).

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CONCLUSION

Compared to control conditions, both the continuous and the interval endurance exercise protocol employed in the present study reduced the total number of repetitions to failure performed in a subsequent half-squat exercise session.

Despite a similar impairment in strength exercise total volume with the two endurance modes, the intermittent protocol (effort: rest = 2:1) caused an acute interference in strength exercise performance throughout the three sets of the half-squat exercise, while the continuous protocol performed at the anaerobic threshold hampered half-squat performance only in the first and second sets.

These findings highlight that regardless of the endurance exercise mode, a previous endurance session may impair the quality of the subsequent lower limb strength exercise sessions in young women.

These findings highlight that the aerobic training performed at the beginning of the session of concurrent training at the analyzed intensities (100% HR_{AT} for continuous and sprints 2:1 at 100% vVO_{2max} for intermittent protocol) may impair the quality of the subsequent lower limb strength exercise sessions in young women.

Therefore, if the aim is to improve strength and muscle hypertrophy, caution must be taken when choosing the training order.

The aerobic training performed at the analyzed intensities should be avoided before the strength training in order to minimize the interference effect during the training session and consequently in the neuromuscular adaptations along the training.

REFERENCES

1-Andrade, L.S.; David, G.B.; Wilhelm, E.N.; Pinto, S.S.; Alberton, C.L. Effect of High-Intensity Interval Treadmill Exercise on Subsequent Lower and Upper Limb Strength Performance. Research Quarterly for Exercise and Sport. Vol. 94. 2022. p. 143-150. https://doi.org/10.1080/02701367.2021.1948954

2-Andrade, L.S.; David, G.B.; Krüger, V.L.; Wilhelm, E.N.; Alberton, C.L. High-intensity interval running impairs subsequent upper limb strength performance. The Journal of sports medicine and physical fitness. Vol. 61. 2021. p. 803-809. https://doi.org/10.23736/S0022-4707.20.11458-0

3-Buchheit, M.; Laursen, P.B. High-intensity interval training, solutions to the programming puzzle: part ii: anaerobic energy, neuromuscular load and practical applications. Sports Medicine. Vol. 43. 2013. p. 927-954. https://doi.org/10.1007/s40279-013-0066-5

4-Cadore, E.L.; Izquierdo, M.; Alberton, C.L.; Pinto, R.S.; Conceição, M.; Cunha, G.; … Kruel, L.F.M. Strength prior to endurance intra-session exercise sequence optimizes neuromuscular and cardiovascular gains in elderly men. Experimental Gerontology. Vol. 47. 2012. p. 164-169. https://doi.org/10.1016/j.exger.2011.11.013

5-Chtara, M.; Chaouachi, A.; Levin, G.T.; Chaouachi, M.; Chamari, K.; Amri, M.; Laursen, P.B. Effect of concurrent endurance and circuit resistance training sequence on muscular strength and power development. Journal of Strength and Conditioning Research. Vol. 22. 2008. p. 1037-1045. https://doi.org/10.1519/JSC. 0b013e31816a4419

6-Conceição, M.; Cadore, E.L.; González-Izal, M.; Izquierdo, M.; Liedtke, G.V.; Wilhelm, E.N.; Kruel, L.F.M. Strength training prior to endurance exercise: impact on the neuromuscular system, endurance performance and cardiorespiratory responses. Journal of Human Kinetics. Vol. 44. 2014. p. 171-181. https://doi.org/10.2478/hukin-2014-0123

7-Craig, B.W.; Lucas, J.; Pohlman, R.; Stelling, H. The effects of running, weightlifting and a combination of both on growth hormone release. Journal of Strength and Conditioning Research. Vol. 5, 1991. p. 198-203. https://doi.org/10.1519/00124278-199111000-00005

8-Docherty, D.; Sporer, B. A proposed model for examining the interference phenomenon between concurrent aerobic and strength training. Sports Medicine. Vol. 30. 2000. p. 385-394. https://doi.org/10.2165/00007256-200030060-00001

9-Howley, E.T.; Bassett, D.R.; Welch, H.G. Criteria for maximal oxygen uptake: review and commentary. Medicine and Science in Sports and Exercise. Vol. 27. 1995. p.1292-1301.

10-Hug, F.; Decherchi, P.; Marqueste, T.; Jammes, Y. EMG versus oxygen uptake during cycling exercise in trained and untrained subjects. Journal of Electromyography and Kinesiology. Vol. 14. 2004. p. 187-195. https://doi.org/10. 1016/S1050-6411(03)00081-6

11-Leveritt, M.; Abernethy, P.J.; Barry, B.K.; Logan, P.A. Concurrent strength and endurance training. A review. Sports Medicine. Vol. 28. 1999, p. 413-427. https://doi.org/10. 2165/00007256-199928060-00004

12-Leveritt, M.; Abernethy, P.J. Acute effects of high-intensity endurance exercise on subsequent resistance activity. Journal of Strength and Conditioning Research. Vol. 13. 1999. p. 47-51. https://doi.org/10.1519/001 24278-199902000-00009

13-Mielke, G.I.; Silva, I.C.M.; Owen, N.; Hallal, P.C. Brazilian adults' sedentary behaviors by life domain: Population-based study. PloS One. Vol. 9. 2014. p. e91614. https://doi.org/10. 1371/journal.pone.0091614

14-Milanovic, Z.; Sporiš, G.; Weston, M. Effectiveness of high-intensity interval training (HIT) and continuous endurance training for VO_2 max improvements: a systematic review and meta-analysis of controlled trials. Sports Medicine. Vol. 45. 2015. p. 1469-1481. https://doi.org/10.1007/s40279-015-0365-0

15-Panissa, V.L.G.; Tricoli, V.A.A.; Julio, U.F.; Ribeiro, N.; de Azevedo Neto, R.M.A.; Carmo, E.C.; Franchini, E. Acute effect of high-intensity aerobic exercise performed on treadmill and cycle ergometer on strength performance. Journal of Strength and Conditioning Research. Vol. 29. 2015. p. 1077-1082. https://doi.org/10. 1519/JSC.0000000000000706

16-Panissa, V.L.G.; Julio, U.F.; Pinto e Silva, C.; Vidal Andreato, L.; Hardt, F.; Franchini, E. Effects of interval time between high-intensity intermittent aerobic exercise on strength performance: Analysis in individuals with different training background. Journal of Human Sport and Exercise. Vol. 7. 2012. p.815-825. https://doi.org/10.4100/jhse.2012.74.09

17-Lombardi, V.P. Beginning weight training: The safe and effective way. Dubuque, United States of America: Brown & Benchmark Pub. 1989.

18-Pinto, S.S.; Alberton, C.L.; Bagatini, N.C.; Zaffari, P.; Cadore, E.L.; Radaelli, R.; … Kruel, L.F.M. Neuromuscular adaptations to water-based concurrent training in postmenopausal women: Effects of intrasession exercise sequence. AGE. Vol. 37. 2015. p. 6. https://doi.org/10.1007/s11357-015-9751-7

19-Reichert, F.F.; Barros, A.J.D.; Domingues, M.R.; Hallal, P.C. The role of perceived personal barriers to engagement in leisure-time physical activity. American Journal of Public Health. Vol. 97. 2007. p. 515-519. https://doi.org/10.2105/AJPH.2005.070144

20-Schumann, M.; Mykkänen, O.-P.; Doma, K.; Mazzolari, R.; Nyman, K.; Häkkinen, K. Effects of endurance training only versus same-session combined endurance and strength training on physical performance and serum hormone concentrations in recreational endurance runners. Applied Physiology, Nutrition, and Metabolism. Vol. 40. 2015 p. 28-36. https://doi.org/10.1139/apnm-2014-0262

21-Sebastião, E.; Chodzko-Zajko, W.; Schwingel, A.; Gobbi, L.T.B.; Papini, C.B.; Nakamura, P.M.; Gobbi, S. Perceived barriers to leisure time physical activity: What Brazilians have to say? Open Journal of Preventive Medicine. Vol. 03. 2013. p. 491-499. https://doi.org/10.4236/ ojpm.2013.38066

22-Souza, E.O.; Tricoli, V.; Franchini, E.; Paulo, A.C.; Regazzini, M.; Ugrinowitsch, C. Acute effect of two aerobic exercise modes on maximum strength and strength endurance. Journal of Strength and Conditioning Research. Vol. 21. 2007. p. 1286-1290. https://doi.org/10. 1519/R-20686.1

23-Sporer, B.C.; Wenger, H.A. Effects of aerobic exercise on strength performance following various periods of recovery. Journal of Strength and Conditioning Research. Vol. 17. 2003. p. 638-644. https://doi.org/10.1519/1533-4287 (2003)017<0638:eoaeos>2.0.co;2

24-Wasserman, K. The Dickinson W. Richards lecture. New concepts in assessing cardiovascular function. Circulation. Vol. 78.

RBPFEX
Revista Brasileira de Prescrição e Fisiologia do Exercício

1988. p. 1060-1071. https://doi.org/10.1161/01.CIR.78.4.1060

25-Wilhelm, E.N.; Rech, A.; Minozzo, F.; Botton, C.E.; Radaelli, R.; Teixeira, B.C.; Pinto, R.S. Concurrent strength and endurance training exercise sequence does not affect neuromuscular adaptations in older men. Experimental Gerontology. Vol. 60. 2014. p. 207-214. https://doi.org/10.1016/j.exger. 2014.11.007

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