Original article

Does high intensity interval training (HIIT) affect strength training performance?

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Summary

Objective: To assess the effect of high intensity interval training (HIIT) on the subsequent performance of strength training (ST) in lower limbs.
Methods: 10 men (23.4 ± 2.4 years, 78.9 ± 8.0 kg, height 1.78 ± 0.08 m, BMI 24.80 ± 1.16, % G 12.3 ± 2, 5; $VO_{2máx}$ 50.9 ± 3.6 ml / kg / min) were subjected to anthropometric, cardiorespiratory and 10 maximum repetition (10RM) tests. At time 1 (M1) the ST was made up of 3 sets of repetitions until the concentric failure for 100% of 10RM, with intervals of 3 minutes between sets in the exercise leg press 45º (LP). Three minutes later the sitting femoral exercise (FS) was started, with the same procedures as before. At time 2 (M2) a HIIT session composed of 10 1 'stimuli with intensity between 90 and 95% HR_{max} (Borg 9 - 10) was performed, interspersed with 10 1' recoveries with intensity between 70 and 75% FC_{max} (Borg 6 - 7). Immediately after, the ST was performed with the same M1 procedures. The strength performance of the lower limbs was determined by the number of repetitions performed in M1 and M2.
Results: There was a reduction in the total of repetitions in the M2 both in the LP (Δ% = -22.97, p-value = 0.0001) and in the FS (Δ% = -17.56%; value = 0.0001) compared to M1. In M2 there was a reduction only in the 3rd series of LP in the intra-group analysis, and intergroup reduction in the three series of M2 compared to M1. For FS, intragroup reduction was observed in the 3rd series of M1 and M2, in addition to intergroup reduction in the 1st and 3rd series of M2 compared to M1.
Conclusion: HIIT, with the characteristics of volume and intensity prescribed in the present study, was able to exert negative interference on the subsequent performance in ST in lower limbs.

Key words:
Physical exercise. Interval training. Strength training. Concurrent training.

¿Afecta el entrenamiento intervalado de alta intensidad (HIIT) al desempeño en el entrenamiento de la fuerza?

Resumen

Objetivo: Valorar el efecto del entrenamiento intervalado de alta intensidad de (HIIT) sobre el subsiguiente desempeño del entrenamiento de la fuerza (EF) en miembros inferiores.
Métodos: 10 hombres (23,4 ± 2,4 años; 78,9 ± 8,0 kg; Estatura 1,78 ± 0,08 m; IMC 24,80 ± 1,16; %G 12,3 ± 2,5; $VO_{2máx}$ 50,9 ± 3,6 ml/kg/min) fueron sometidos a mediciones antropométricas, cardiorrespiratorias y prueba de 10 repeticiones máximas (10RM). En el momento 1 (M1) se realizó el EF compuesto por 3 series de repeticiones hasta el fallo concéntrico para el 100% de 10RM, con intervalos de 3 minutos entre series en el ejercicio leg press 45º (LP). Tres minutos después se inició el ejercicio de femoral sentado (FS), con los mismos procedimientos anteriores. En el momento 2 (M2) se realizó una sesión de HIIT compuesta por 10 estímulos de 1' con intensidad entre el 90 y 95% $FC_{máx}$ (Borg 9 - 10), intercalados con 10 recuperaciones de 1' con intensidad entre 70 al 75% $FC_{máx}$ (Borg 6 - 7). Inmediatamente después, se realizó el EF con los mismos procedimientos del M1. El rendimiento de la fuerza de los miembros inferiores fue determinado por el número de repeticiones ejecutadas en M1 y M2.
Resultados: Hubo una reducción en el total de repeticiones en el M2 tanto en el LP (Δ%= -22,97; p-valor=0,0001) como en el FS (Δ%= -17,56%; p-valor=0,0001) en comparación con el M1. En M2 hubo una reducción sólo en la 3ª serie del LP en el análisis intragrupo, y reducción intergrupos en las tres series del M2 en comparación con M1. Para el FS, se observó reducción intragrupo en la 3ª serie de M1 y M2, además de reducción intergrupos en la 1ª y 3ª serie de M2 en comparación con M1.
Conclusión: El HIIT, con las características de volumen e intensidad prescritas en el presente estudio, fue capaz de ejercer interferencia negativa sobre el subsiguiente desempeño en el EF en miembros inferiores.

Palabras clave:
Ejercicio físico. Entrenamiento intervalado. Entrenamiento de fuerza. Entrenamiento concurrente.

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Introduction

The benefits of regular physical exercise to the health and the importance of including aerobic and muscle-strengthening activities in such exercise are well documented[1]. Regular physical exercise brings health improvements, such as increased maximal oxygen uptake, an increase in lean body mass, a reduction in systolic (SBP) and diastolic blood pressure (DBP) in repose, increased HDL cholesterol levels, reduced LDL cholesterol levels and greater glucose tolerance[2].

The types of physical exercise available include strength training and aerobic endurance training. High-intensity interval training (HIIT) is one of the ways in which aerobic exercise can be performed to promote positive physiological adaptations as a result of metabolic alterations and ionic homeostasis[3]. HIIT is part of training for such sports as football, handball, basketball, cycling and running[4]. Athletes and specialists are interested in perfecting and including this method in their training programmes[5] with an eye to improving performance[6].

Another type of training considered important to improve performance is strength training (ST). It is used both to maintain health in the general population and to improve the performance of athletes[7]. ST is recommended in order to increase muscle mass and enhance strength, fitness and the health[8,9]. In practice, different physiological responses, such as improved integrated operation of the nervous and muscular systems (neural adaptations), and the hypertrophic effects of training, can be obtained by manipulating the variables involved (exercise order, time interval between sets and exercises, number of sets and repetitions, fractioning training, etc.).

A combination of aerobic exercise and strength training in a single session is called concurrent training (CT)[10]. Athletes and physically active individuals often use this type of training[11] because the benefits of both systems can be accrued at the same time[12]. In CT, aerobic exercise is used to reduce body fat stores and strength training is used to try to preserve or increase lean mass[13].

However, certain considerations should be taken into account regarding this method, since it would appear that a combination of different training systems in a single training session may negatively affect performance[14-16].

The aim of this study was to evaluate the effect of high intensity interval training on subsequent performance during strength training involving the lower limbs.

Material and method

Sample

The sample consisted of 10 male volunteers who had at least six months' experience of strength training sessions lasting over 60 minutes more than four times a week. According to the risk stratification criteria of the *American Heart Association* (AHA)[17], the individuals did not exhibit any apparent risk factors preventing them from taking part in the research.

The study adopted the following criteria for exclusion: a) the existence of degenerative or metabolic diseases, injuries or musculoskeletal limitations which might prevent performance of the exercises programmed, or cardiovascular disorders; b) the use of ergogenic/nutritional substances.

The study respected the standards for research involving human beings set out in Resolution 466/2012 of the Brazilian National Health Council and the Declaration of Helsinki[18]. The study project was approved by the Research Ethics Committee of the Federal University of Rio de Janeiro (number 983.976 / 2015).

Data collection procedures

Each volunteer paid five non-consecutive visits, always at the same time and with intervals of 48 to 72 hours, depending on their availability. On their first visit, the participants were informed about all the study procedures and responded to the AHA questionnaire. Their anthropometric measurements were taken and they performed the 10 repetition maximum test (10RM). On their second visit, they did a 10RM re-test. On their third visit, an ergometer test was performed to estimate relative maximal oxygen uptake (mlO_2/kg/min) and their HR_{Rest} (after 10 minutes of rest) and HR_{max} variables were measured. The study sessions were held on the fourth and fifth visits.

Anthropometric measurements

Height was measured using a Sanny® ES2020 professional stadiometer (Brazil). Body composition was evaluated by bioelectrical impedance analysis (BIA) using a Biospace InBody® 230 (South Korea) with a capacity of 250 kg and an accuracy of 100 g. The body mass index (BMI) was calculated by dividing total body mass (TBM) by height (m) squared. All the anthropometric measurements were taken following the specific protocols recommended in the *International Standards for Anthropometric Assessment* (ISAK)[19].

10 repetition maximum test (10RM)

10 repetition maximum testing and re-testing (10RM) took place in a single day on 45º leg press (LP) and seated leg curl (SLC) equipment, following the recommendations of Baechle and Earle[20]. The 10RM test was chosen due to its high correlation with the muscle strength registered with 1 repetition maximum (1RM) and a lower injury rate[21].

Testing and re-testing were halted when the individuals could not complete the movement, with voluntary concentric interruption at 10RM[22]. The movement execution speed was approximately 2 seconds for each movement phase.

If the load for 10RM was not obtained after three attempts, the test was called off and carried out the next non-consecutive day previously scheduled. The intervals between attempts at each exercise during 10RM testing and/or re-testing were set at 5 minutes. 10RM was considered to be the highest load achieved in the two days with a difference of less than 5% and if the difference in the loads moved was equal to or greater than 5%, a new re-test was arranged to check the reproducibility of the load[23]. After obtaining the load in the particular exercise, there were recovery intervals of no less than 10 minutes before moving on to testing with the next strength exercise[24].

All the tests and re-tests took place at times similar to those at which the individuals usually trained, were carried out at a controlled temperature of between 18 ºC to 22 ºC and were monitored by an experienced evaluator. There was an intraclass correlation coefficient (ICC) of 0.95. The study participants were instructed not to perform physical exercises of any kind and not to take stimulants in the 24 hours prior to both data collection and the study itself.

Maximum Heart Rate (HR_{max})

In order to prescribe and control the intensity of HIIT, the volunteers' HR_{max} was measured using an incremental treadmill test (Inbramed® Master ATL, Brazil) according to the protocol proposed by Bruce[25]. The individuals' heart rates were monitored with a Polar® S210 (Finland) heart rate monitor. In order to characterise the sample group, maximal oxygen uptake (VO_{2max}) was estimated in the same test.

Study

In the first study session (S1), the participants were subjected to ST on the LP and SLC equipment. The specific warm-up consisted of 1 set of 15 repetitions on the LP at 50% of the maximum load obtained in 10RM testing and/or re-testing. Three minutes after the warm-up, 3 sets of repetition to voluntary concentric failure were performed at an intensity of 100% 10RM, with intervals of 3' between sets. Three minutes after the 3rd LP set, the 3 sets on the SLC equipment began, following the same procedures in terms of volume and intensity.

In the second study session (S2), the subjects, monitored by a heart rate monitor, were subjected to HIIT, according to the protocol adapted by Gibala *et al.*[26], which consisted of 30 minutes on the treadmill (Life Fitness 95T with Flex Deck Shock Absorption System, USA) without incline, divided into: a) 5' warm-up at an intensity of 50 to 55% HR_{max}; b) specific phase lasting 20' divided into 10 stimuli of 1' at an intensity of 90 to 95% HR_{max} and perceived exertion between 9 and 10 on the Borg scale (CR10)27, interspersed with 10 active intervals lasting 1' at an intensity of 70 to 75% HR_{max} and perceived exertion between 6 and 7; c) 5' cool-down at an intensity of 50% HR_{max}. Immediately after HIIT, the participants performed the ST, following the same procedures as those in S1. However, in this stage the ST was not preceded by the specific LP and SLC warm-up.

Lower limb strength performance was determined by the number of repetitions completed in each of the ST sets carried out in the different study sessions.

Data analysis

The data were processed using the *Statistical Package for Social Sciences* (SPSS statistics 20 - Chicago, USA) and were presented as mean, standard deviation and minimum and maximum values. The normality and homogeneity of the sample data were verified with the Shapiro-Wilk test and Levene's test, respectively. On the basis of the results, it was decided that a paired Student's t-test should be used to analyse the total number of repetitions completed between the study sessions. Repeated measures ANOVA, followed by Tukey's Post-hoc test, was used for intra- and inter-study protocol analysis. The level of significance was set at $p < 0.05$.

Results

Table 1 shows the data relevant to the body composition and cardiorespiratory fitness of the volunteers. The results of the Shapiro-Wilk test for the variables mentioned showed a near normal distribution curve.

Figure 1 depicts analysis of the number of repetitions completed in each series carried out on the LP apparatus in the two study sessions (S1 and S2).

After intragroup analysis, a significant difference was observed only in the third ($F = 3.269$; $p = 0.04$) set of S2. No differences were observed in S1. Intergroup analysis revealed a significant reduction in the number of repetitions in the first ($F = 5.828$; $p = 0.02$), second ($F = 7.531$; $p = 0.01$) and third ($F = 15.818$; $p = 0.001$) sets of S2 compared to S1.

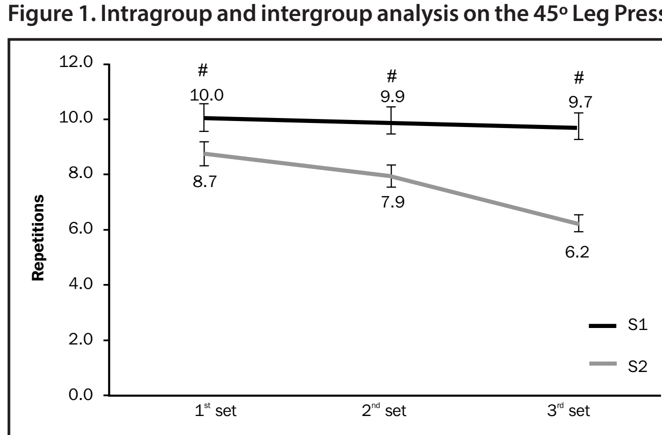
Figure 2 depicts analysis of the number of repetitions completed in each series carried out on the SLC apparatus in the two study sessions (S1 and S2).

Table 1. Body composition and cardiorespiratory fitness.

	Age (years)	TBM (kg)	H (m)	BMI (kg/m²)	%F	VO_{2max} (ml/kg/min)
Mean	23.4	78.9	1.78	24.8	12.3	50.9
SD	2.4	8.0	0.08	1.16	2.5	3.6
SW (p-value)	0.32	0.71	0.72	0.94	0.78	0.39

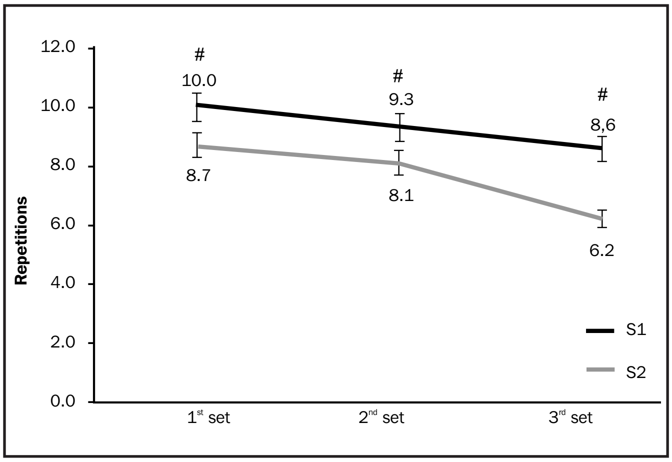
TBM: total body mass; H: height; BMI: body mass index; %F: percentage of fat mass; SD: standard deviation; SW (p-value): Shapiro-Wilk normality test.

Figure 1. Intragroup and intergroup analysis on the 45º Leg Press.



#Significant intergroup difference; *Significant intragroup difference.

Figure 2. Intragroup and intergroup analysis on the Seated leg curl machine.



#Significant intergroup difference; *Significant intragroup difference.

Table 2. Total number of repetitions.

Equipment	S1	S2	Δ%	p-value
45º Leg Press	29.6	22.8	-22.97	<0.001
Seated leg curl	27.9	23.0	-17.56	<0.001

After intragroup analysis, a reduction was observed in the third series of both S1 ($F = 7.151$, $p = 0.003$) and S2 ($F = 3.691$, $p = 0.04$) compared to the others. Intergroup analysis showed a significant reduction in the number of repetitions in the first ($F = 5.053$; $p = 0.03$) and third ($F = 7.005$; $p = 0.01$) sets of S2 compared to S1. There were no intergroup differences in the second set ($F = 3.323$, $p = 0.08$).

Table 2 compares and shows the percentage change (Δ%) between the total number of repetitions completed in the three sets of the exercises used in the two study sessions (S1 and S2).

There was a significant reduction ($p < 0.05$) between the total number of repetitions completed by the participants in the three sets on both the LP and SLC machines.

Discussion

The aim of the study was to evaluate the effect of HIIT on lower limb strength performance. When HIIT was performed before ST, the muscle strength of the lower limbs dropped significantly. Aerobic exercise may lead to residual fatigue which affects the ability to perform strength training repetition maximums and one of the possible causes of this fatigue is related to the depletion of creatine phosphate reserves[28,29].

High intensity aerobic training (> 90% VO_{2max}) leads to greater recruitment of motor units consisting of type II fibres, as does strength training involving protocols above 70% 1RM[30]. On analysing the influence of the different methods and intensities of cardiorespiratory exercise on strength performance, only the intermittent method (1 'stimulus with 1' recovery) at a high intensity (90% VO_{2max}) managed to negatively influence strength performance[31]. These intensities were used in this study, corroborating the results presented.

For Simão *et al.*[32], the performance of both large and small muscle groups in exercises carried out last in the sequence of a training programme leads to a lower number of repetitions, especially in the last sets of each exercise. Performance is better in the exercises at the start of a training session, regardless of the size of muscle mass and the number of joints involved. As in the present study, the reduction in the total number of LP repetitions was greater than it was in SLC; this was probably due to the interference of HIIT associated with the neuromuscular exercise performed on the LP.

The findings of Raddi *et al.*[33] suggest that the negative interference of cardiorespiratory training on strength performance depends on the body segment used, because, in their research, no significant differences were observed in dynamic and isometric strength with or without previous cardiorespiratory exercise consisting of running on a treadmill.

Leveritt *et al.*[34] investigated the effects of a session of high intensity cardiorespiratory exercise on lower limb strength, concluding that muscle performance can be inhibited if the strength training session is preceded by incremental exercise on a cycle ergometer at intensities varying between 40% and 100%. These results confirm the results obtained in this study, in which a reduction in muscle performance was observed in the two exercises tested when they were performed after a session of high intensity cardiorespiratory exercise.

Jones *et al.*[35] evaluated the effects of exercise in concurrent training on endocrine responses and strength. The results for strength production suggest that doing cardiorespiratory exercise prior to strength training may lead to acute adaptations which are unfavourable for the development of this variable, particularly at high intensities.

It was found that performance in strength training when preceded by cardiorespiratory training fell by 37.4% compared to strength training in isolation, providing results similar to those of this study. After cardiorespiratory training at an intensity of 70% HRR, the capacity to do 45º leg press strength training at 85% 1RM was significantly lower. The same was observed in the present study.

In the results of this study, the findings of Costa *et al.*[2] showed that cardiorespiratory exercise performed before strength training was not able to negatively influence muscle performance. However, the cardiorespiratory exercise lasted 25' and was carried out at an intensity of 70% HRR using the continuous method. Muscle performance was evaluated with seated knee extension exercise at an intensity of 70% 1RM.

On the basis of the data obtained in this research, it is possible to conclude that muscle performance in both LP and SLC exercise, measured by the number of repetitions completed, fell significantly when carried out after high intensity interval training. It is, therefore, possible to infer that aerobic training, with volume and intensity characteristics as prescribed in this study, can negatively influence lower limb strength performance.

We suggest that future studies use larger samples and longer study times to enable research into the chronic effect of concurrent training on strength performance when performing exercises for the same muscle groups.

Conflict of interest

The authors do not declare a conflict of interest.

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