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Modulation of inflammatory response arising from high-intensity intermittent and concurrent strength training in physically active males

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ABSTRACT

The purposes of this study were to determine: (i) the extent of an acute session of high-intensity intermittent exercise (HIIE) followed by a concurrent strength session (Conc) on the increase of systemic inflammatory cytokines and chemokines, and (ii) whether eight weeks of high intensity interval training plus concurrent strength training alters the acute inflammatory response and immune status. Ten recreationally active males (aged 26.9 ± 4.3 years) performed two experimental exercise sessions interspersed by eight weeks of HIIT plus concurrent strength training. The experimental exercise session was composed of a 5-km run on a treadmill (1:1 at 100% of maximal aerobic speed (MAS)), and after 10 min of passive recovery, back squat exercises were performed (80% 1RM, four sets until exhaustion). Serum samples were collected after fasting, pre-HIIE, post-HIIE, Pre-Conc, Post-Conc, and 30 and 60 min post-exercise session. The comparison between both concurrent exercise sessions was performed using repeated measure ANOVA, with the Bonferroni Post-hoc when necessary. Interleukin-6 (IL-6) presented a moment effect ($F = 6.72$; $p < 0.05$), with Post-Conc significantly higher than pre-HIIE, Post-HIIE, and 60 min, only a tendency was found between pre-HIIE and post-HIIE (difference = –5.99; $p = 0.09$). MCP-1 and IL-1ra did not present effects for condition, moment, or interaction. Interleukin-10 (IL-10) presented both moment and interaction effects ($F = 5.31$ and 2.50; $p = 0.005$ and 0.036). Pre-Conc and Post-Conc were significantly higher than Pre-HIIE. The interaction between before and after eight weeks of concurrent training probably occurred at Post-Conc (11.42 ± 3.09 pg mL^{-1} and 8.88 ± 1.29 pg mL^{-1}). In addition, maintenance of immune function was observed. Therefore, HIIE and concurrent strength exercise lead to an increase in cytokines response, but eight weeks of training program promoted anti-inflammatory response after an acute session of concurrent exercise.

1. Introduction

Exercise controls several functions of the human body, and recently, the discovery of the skeletal muscle as a metabolically active organ has further increased the need to study the effects of training protocols on the production of myokines [1]. Myokines are molecules produced by the skeletal muscle due to contraction, have different functions in the organism, and are capable of acting either locally or in other tissues [2].

Some myokines, such as tumor necrosis factor (TNFα), interleukins 6 and 1 beta (IL-6 and 1β) were found in higher concentrations after strenuous exercise when compared to baseline [3]. In addition, these myokines have been studied in order to investigate the acute anti-inflammatory effects of exercise [4]. Likewise, IL-6 and interleukin-10 (IL-10) play an anti-inflammatory role and have been observed in increased amounts in response to exercise [5–9]. Therefore, exercise is able to modulate inflammatory disorders associated with high levels of myokine and glycoprotein expression in skeletal muscle tissue, leading to changes in immune cells, i.e., reduction in toll-like receptor expression on the cell surface of monocytes and increased frequency of regulatory T cells [1,10].

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These acute changes seem to be able to transiently generate systemic elevation of anti-inflammatory cytokines (mainly IL-10 and interleukin 1 receptor antagonist – IL-1ra), regardless of the modulation of pro-inflammatory cytokines [11,12].

Monocyte chemoattractant protein 1 (MCP-1) is also known to be an important chemokine, and it is responsible for recruitment of monocytes. Thus, targeting MCP-1 may prevent the changes associated with macrophage-induced inflammation [13]. Recent evidence suggest that the adaptive response to exercise is facilitated by a boost of the inflammatory response, mediated through the increase of the non-resident macrophage pool in reaction to a robust elevation in MCP-1 [14]. Interestingly, these events are reported to coincide with a significant reduction in delayed onset of muscle soreness [14], suggesting that the increase of monocyte response via MCP-1 signaling may lead to an enhanced recovery.

Typically, endurance training mediates anti-inflammatory actions that lead to fat loss and improvement of aerobic capacity. However, research recently demonstrated that high-intensity intermittent exercise cause anti-inflammatory responses similarly to moderate-intensity continuous exercise [7–9]. In addition, we have demonstrated that strength exercise and concurrent strength training promote changes in inflammatory response [15–17].

Zwetsloot et al. [9] showed that two weeks of a high intensity interval training (HIIT) program did not alter the inflammatory response after an acute high intensity exercise (HIIE) session. We recently demonstrated that a 5-km HIIE session is able to increase levels of IL-6 and IL-10, similarly to steady state exercise. Lately, concurrent training (i.e., aerobic + strength training in the same session) has been proposed to induce metabolic adaptations [18]. However, Navalta et al. [19] observed that repeated intense interval exercise appears to affect the immunological system, leading to an immunosuppression status by reducing the potential vulnerability to antigens during this timeframe.

Although widely used in the literature [7,8,20–23], little is known about the acute inflammatory response to HIIE followed by concurrent strength exercises, and the effects of concurrent training on inflammatory response. Indeed, understanding the immunometabolic effects of HIIE plus strength training is crucial for clinical practice, once it gains more followers around the world. Therefore, the aim of study was to analyze the inflammatory response of concurrent exercise (HIIE + strength training) after eight weeks of training among physically active subjects.\

2. Methods

2.1. Subjects

The sample consisted of 10 males aged between 18 and 35 (26.9 ± 4.3) years old (Table 1). The participants were considered physically active according to aerobic conditioning determined by VO_{2Peak} and presented no characteristics of any clinical problem that could prevent physical activity. The subjects participated voluntarily in the study after being informed of the procedures, risks, and benefits, and signed an consent form. This study was approved by the Ethics Committee (22793414.7.0000.5402).

Table 1
Mean and standard deviation of IL-6, IL-10, MCP-1, and IL-1ra at the 1st week and after eight weeks of concurrent training (n = 10).

Variables	Pre-training (1st week)	Post-training (8th week)	p-value
Weight (kg)	74.13(7.8)	74.97(8.2)	0.121
VO_{2max}	53.60(3.6)	54.52(3.8)	0.000
1RM	113.50(22.9)	135.20(24.4)	0.001
Inflammatory markers			
IL-6 (pg mL^{-1})	10.94 ± 6.27	9.79 ± 5.08	0.60
IL-10 (pg mL^{-1})	8.08 ± 1.59	8.27 ± 1.56	0.78
MCP-1 (pg mL^{-1})	137.87 ± 29.90	128.51 ± 20.81	0.80
IL-1ra (pg mL^{-1})	716.67 ± 454.65	763.85 ± 469.66	0.86

2.2. Experimental design

In order to analyze acute inflammatory response before and after concurrent training, the participants were submitted to a concurrent exercise session (Pre-training), followed by eight weeks of concurrent training, and another concurrent exercise session (Post-training). Prior to the Pre-training period, participants were familiarized with the half-squat exercise. After adaptation, they were submitted to (i) one incremental exercise test in order to determine maximal aerobic speed (MAS) and, (ii) one maximal repetition of half-squat with guided bar (1-RM). At least 48 h after the tests, the subjects performed both Pre-training and Post-training. Between the tests the subjects trained twice a week for eight weeks (Fig. 1).

2.3. Incremental test

To determine aerobic fitness, the participants performed a maximal incremental test on the treadmill (Inbramed-ATL) until exhaustion, with the measurement of maximum oxygen consumption (Model Quark PFT Ergo - Cosmed - Rome) ($\dot{V}O_2$). Each stage of the test lasted two minutes; the first stage was performed at 8 km h^{-1}, increasing by 1 km h^{-1} at the end of each stage. In addition, heart rate was monitored using a heart rate monitor (Polar Vantage NV, Electro Oy, Finland) integrated into the gas analysis system. The average of the final 30 s was defined as peak oxygen uptake ($\dot{V}O_{2peak}$). The maximal speed reached in the test was defined as the peak speed (S_{peak}). When the participant was not able to finish the two minutes stage, the speed was expressed according to the permanence time in the final stage, determined as the following equation: S_{peak} = speed of penultimate stage + [(time, in seconds, remained in the final stage multiplied by 1 km h^{-1})/120 s] [24].

2.4. Maximum dynamic strength test

Seventy-two hours after the maximum endurance running test, the participants performed the maximum dynamic strength test. It consisted of the maximum load that the individual was able to lift in just one-repetition maximum (1RM) in the half squat exercise with a guided bar. The recommendations of the American Society of Exercise Physiology were used for this test [25].

Before performing the 1RM test, participants were familiarized with the half squat exercise, during which they executed the medium squat twice for 15–20 repetitions, the first with no weight and the second with 10–15 kg weight, for three days, once a day, for adaptation to the machine and for the correct execution of the movement.

Subsequently, the 1RM test was performed after a five minutes warm-up at 50% of vVO2max. Next, subjects performed eight repetitions at the estimated intensity of 50% 1RM, followed by another three repetitions at 80% estimated 1RM. Attempts to establish the 1RM were only executed with progressively heavier weight until fatigue. The resting interval was three to five minutes and the number of attempts was no more than five. The highest weight lifted in the test was regarded as the value of 1RM.

For better control of the 1RM test procedures, body position and feet placement of each participant in the half-squat exercise was recorded and reproduced throughout the study. In addition, a woo-