Hormonal and Inflammatory Responses to Different Types of Sprint Interval Training

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[1]Zinman College of Physical Education, Wingate Institute, Netanya, Israel; [2]Child Health and Sport Center, Pediatric Department, Meir General Hospital, Sackler School of Medicine, Tel-Aviv University, Israel; and [3]Pediatric Exercise Research Center, Department of Pediatrics, University Children's Hospital, University California, Irvine, California.

Abstract

Meckel, Y, Nemet, D, Bar-Sela, S, Radom-Aizik, S, Cooper, DM, Sagiv, M, and Eliakim, A. Hormonal and inflammatory responses to different types of sprint interval training. *J Strength Cond Res* 25(8): 2161–2169, 2011—We evaluated the effect of different types of sprint interval sessions on the balance between anabolic and catabolic hormones and circulating inflammatory cytokines. Twelve healthy elite junior handball players (17–25 years) participated in the study. Exercise consisted of increasing distance (100 m, 200 m, 300 m, 400 m) and decreasing distance (400 m, 300 m, 200 m, 100 m) sprint interval runs on a treadmill (at random order), at a constant work rate of 80% of the personal maximal speed (calculated from the maximal speed of a 100 m run). The total rest period between the runs in the different interval sessions were similar. Blood samples were collected before, after each run, and after 1-hour recovery. Both types of sprint interval trainings led to a significant ($p < 0.05$) increase in lactate and the anabolic factors growth hormone, insulin-like growth factor-I (IGF-I), IGF binding protein-3 (IGFBP-3), and testosterone levels. Both types of sprint interval sessions led to a significant ($p < 0.05$) increase in the circulating pro- and anti-inflammatory mediators IL-1, IL-6, and IL1ra. IL-6 remained elevated in both sessions after 1-hour recovery. Area under the curve was significantly greater ($p < 0.05$) for lactate and growth hormone (GH) in the decreasing distance session. In contrast, rate of perceived exertion was higher in the increasing distance session, but this difference was not statistically significant ($p = 0.07$). Changes in anabolic-catabolic hormones and inflammatory mediators can be used to gauge the training intensity of anaerobic-type exercise. Changes in the GH-IGF-I axis and testosterone level suggest exercise-related anabolic adaptations. Increases in inflammatory mediators may indicate their important role in muscle tissue repair after anaerobic exercise. The decreasing distance interval was associated with a greater metabolic (lactate) and anabolic (GH) response but not with a higher rate of perceived exertion. Coaches and athletes should be aware of these differences, and as a result, of a need for specific recovery adaptations after different interval training protocols.

Key Words anaerobic exercise, cytokines, growth hormone, IGF-I, interval training

Introduction

Interval training is one of the most frequent training methods used in anaerobic and aerobic-type sports (10). The intensity of such training depends on the running distance (sprint versus long distance), running speed (percent of maximal speed), the number of repititions, and the length of the rest interval between runs. In addition, coaches and athletes change very often the style of the interval training and use constant running distances (eg, 6 × 200 m), increasing distance interval session (eg, 100 m, 200 m, 300 m, 400 m), decreasing distance interval session (eg, 400 m, 300 m, 200 m, 100 m), or a combination of increasing-decreasing distance interval session (eg, 100 m, 200 m, 300 m, 200 m, 100 m). Although these style differences may seem negligible, they may involve different physiological demands (eg, heart rate) because in the increasing distance protocol, metabolic demands (eg, lactate levels) increase gradually and are highest toward the end of the session, whereas in the decreasing distance protocol, the metabolic demands are higher from the beginning of the session (13). In recent years, in an attempt to optimize training, efforts are made to quantify, by objective measures, the balance between the interval training load and the athlete's ability to tolerate it.

Recent reports demonstrated, rather surprisingly, that exercise leads to a simultaneous increase in antagonistic circulating mediators. On one hand, exercise stimulates anabolic components of the growth hormone (GH)→insulin-like growth factor-I (IGF-I) axis (1,19), and on the other hand,

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exercise increases catabolic pro-inflammatory cytokines such as interlukin-6 (IL-6) (14,16). Thus, it is suggested that evaluation of the balance and changes in these circulating mediators after different types of exercise training will assist in the efforts to quantify training loads.

Most previous studies on the GH→IGF-I axis and inflammatory cytokines response to exercise focused on *endurance-type* and *resistance* exercise bouts and/or training (14–16), whereas the effect of typical *anaerobic* exercise on these mediators was not extensively studied. We recently reported that *anaerobic-type* sprint interval training (4 × 250 m) lead to a comparable simultaneous increase in anabolic and inflammatory mediators (12). The aim of the present study was to evaluate the effect of increasing and decreasing distance sprint interval training protocols, 2 common types of sprint interval training, on the balance between anabolic and catabolic hormones, and circulating cytokines. We hypothesized that consistent with metabolic demands, the catabolic and inflammatory response to exercise will be more pronounced in the decreasing distance, compared with the increasing distance protocol.

Methods

Experimental Approach to the Problem

After our initial report on the effect of a typical anaerobic exercise training session on the GH-IGF-I axis and on inflammatory cytokines (12), we evaluated the effect of 2 common sprint interval training protocols at increasing and decreasing distances, known to lead to different physiological and metabolic responses (13), on the balance between anabolic/catabolic hormones and circulating cytokines.

The athletes participated in 2 separated sprint interval sessions. The total distance (1000 m), speed (80% of maximal speed) and rest period (total rest 9 minutes) were equal in both interval sessions. At random order, the athletes performed either an increasing distance run (100 m, 200 m, 300 m, 400 m runs), or a decreasing distance run (400 m, 300 m, 200 m, 100 m). Hormonal measurements included circulating levels of the anabolic hormones GH, IGF-I, IGF-binding protein-3 (IGFBP-3) and testosterone, IGFBP-1–a binding protein that inhibits the anabolic effects of IGF-I and the catabolic hormone cortisol. Measurements of inflammatory mediators included the pro-inflammatory markers IL-6 and the anti-inflammatory marker IL-1 receptor antagonist (IL-1ra). Serum lactate was measured, as a surrogate marker for the assessment of training intensity. In addition, rate of perceived exertion (RPE) was used to assess the participants self-perception of each interval session intensity (2).

Subjects

Twelve healthy elite Israeli junior handball players (age range 17–25 years) participated in the study. All participants played in the Israeli premier handball league, and some of them played in the Israeli national junior handball team. The study was performed during the final stages of the regular handball season when the players are at their best form. Training at this stage of the season involved mainly tactic and technical drills emphasizing handball skills and team strategies, speed drills with and without the ball, and longer interval sessions (eg, several repetitions of 20–40 seconds run at 80% of the maximal speed). No resistance training was done at the time of the study. Anthropometric characteristics of the participants are summarized in Table 1. Standard calibrated scales and stadiometers were used to determine height, body mass, and body mass index. Skin-fold measurements at 4 sites (triceps, biceps, subscapular and supra-iliac) were used to calculate percent body fat using standard equations (11). The study was approved by the Institutional Review Board of the Meir medical center. Participants were informed of the experimental risks and signed an informed consent before the investigation.

Procedure

Exercise Protocol. Each participant performed 2 maximal outdoors 100 m runs. The best result was used to calculate the speed of the runs during the interval exercise sessions. Each subject participated in 2 separate interval exercise sessions. The total distance (1000 m) and rest period (total rest: 9 minutes) was equal in both interval sessions. However, at random order, the athletes either performed an increasing distance running practice (100 m, 200 m, 300 m, 400 m runs at 80% of the maximal speed calculated from the speed of the 100 m run) or a decreasing distance running practice (400 m, 300 m, 200 m, 100 m at the same relative speed) (Figure 1). The training was performed on a treadmill (motor-driven treadmill; Woodway, PPS Med, Weil am Rhein, Germany), in constant ambient conditions.

Blood Sampling and Analysis. Tests were performed in the morning, after an overnight fast. An indwelling venous catheter was inserted 30 minutes before the first blood draw. Pre, immediately after every run (within 2 minutes from the end of each run), and 60 minutes post the last exercise (recovery), blood samples were drawn from the catheter (Figure 1). Blood samples were immediately spun at 3000 rpm, at 4°C for 20 minutes. The serum was separated and stored at −80°C. All pre-exercise and postexercise specimens

Table 1. Anthropometric characteristics of the study participants.

Age (yrs)	20.3 ± 1.0
Body weight (kg)	74.5 ± 2.3
Body height (cm)	179.7 ± 2.1
BMI (kg/m^2)	23.1 ± 0.8
Body fat (%)	13.7 ± 0.6

BMI = body mass index.

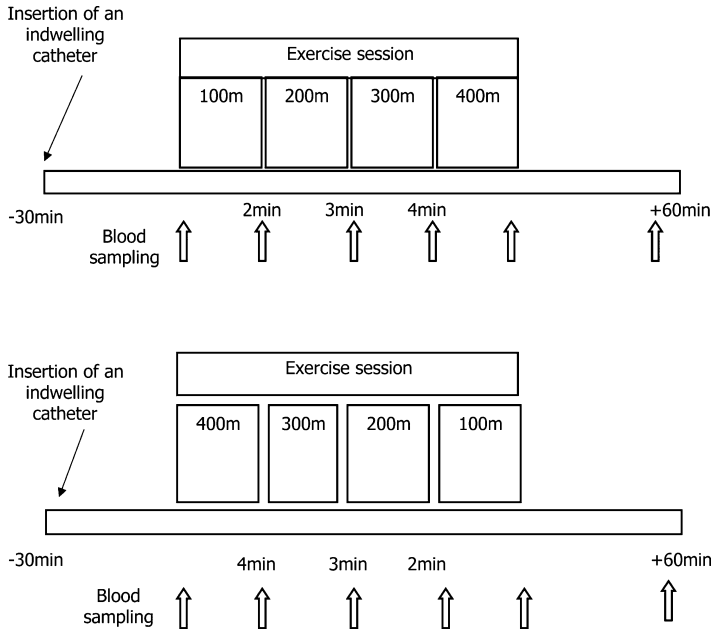

Figure 1. The exercise protocol and blood sampling procedure of the study.

from each individual were analyzed in the same batch by an experienced technician who was blinded to the type of interval training and order of samples.

Growth Hormone. GH serum concentrations were determined by enzyme-linked immunosorbent assay (ELISA) with the use of the DSL-10-1900 Active kit (Diagnostic System Laboratories, Webster, Texas, USA). Intra-assay CV was 3.3–4.5%, interassay CV was 5.5–12.9%, and the sensitivity was 0.03 ng/mL.

Insulin-Like Growth Factor-I. IGF-I was extracted from IGF-binding proteins (IGFBPs) by using the acid-ethanol extraction method. Serum IGF-I concentrations were determined by a 2-site immunoradiometric assay by using the DSL-5600 Active kit (Diagnostic System Laboratories). IGF-I intra-assay CV was 1.5–3.4% and the interassay CV was 3.7–8.2%. Assay sensitivity was 0.8 ng/mL.

IGF Binding Proteins. IGFBP-1 was measured by a coated-tube immunoradiometric assay with the use of the DSL-10-7800 Active kit (Diagnostic System Laboratories). Intra-assay CV was 2–4%, and interassay CV was 1.7–6.7%. Assay sensitivity is 0.33 ng/mL. IGFBP-3 serum concentrations were determined by ELISA with the use of the DSL 10-6600 Active kit (Diagnostic System Laboratories). Intra-assay CV was 7.3–9.6%, interassay CV was 8.2–11.4%, and the sensitivity was 0.04 ng/mL.

Lactate. Blood lactate concentration was measured by finger-prick using a portable lactate analyzer (Accusport,

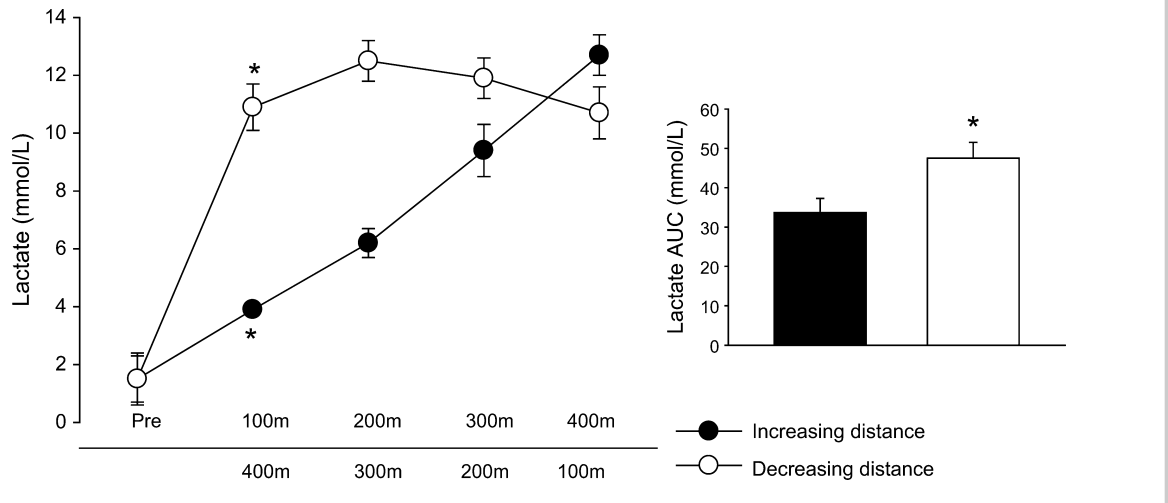

Figure 2. The effect of increasing and decreasing distance sprint interval on circulating lactate level. Exercise was associated with a significant increase of lactate in both sessions (*$p < 0.05$). Lactate AUC (Rt. panel) was significantly greater in the decreasing distance intervals.

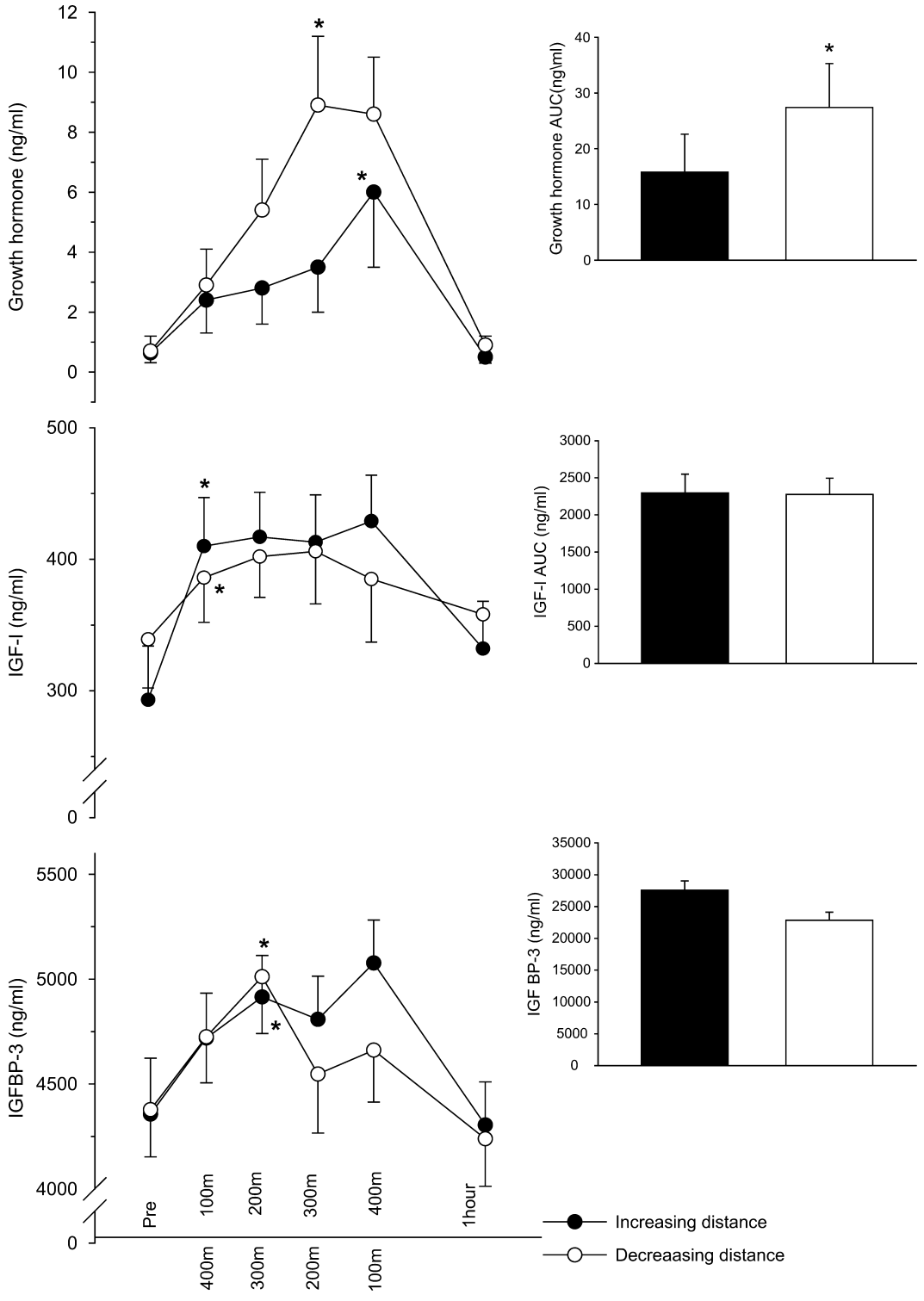

Figure 3. The effect of decreasing and increasing distance sprint interval exercise on circulating components of the GH-IGF-I axis. Exercise was associated with a significant increase of GH, IGF-I and IGFBP-3 in both sessions (*$p < 0.05$). Values returned to baseline levels during recovery. AUC (right panel) was significantly different only for GH, in the decreasing distance intervals.

Boehringer Mannehein, Germany) at the rest interval after each sprint.

Cortisol. Serum cortisol levels were determined by a commercial radioimmunoassay (Diagnostic Products Corporation, Los Angeles, CA, USA). The intra-assay and interassay CV for this assay were 3.2% and 6.8%, respectively.

Testosterone. Testosterone serum concentrations were determined by ELISA with the use of the DSL commercial kit (Diagnostic System Laboratories). Intra-assay CV was 4.8–5.3%, interassay CV was 2.8–4.9%, and the sensitivity was 0.04 ng/mL.

Inflammatory Mediators. Inflammatory mediators were analyzed by ELISA with the use of the R&D system Quantikine High Sensitivity commercial kits (R&D system; Minneapolis, MN, USA). IL-6: Intra-assay CV was 3.8–11.1%, interassay CV was 7.1–29.5%, and the sensitivity was 0.0094 pg/mL. Interleukin-1 beta: Intra-assay CV was 1.6–4.0%, interassay CV was 5.3–9.0%, and the sensitivity was 0.059 pg/mL. IL-1ra: Intra-assay CV was 3.1–6.2%, interassay CV was 4.4–6.7%, and the sensitivity was 22 pg/mL. Interleukin-10 (IL-10): intra-assay CV was 8.1–15.6%, interassay CV was 6.6–8.2%, and the sensitivity was 0.5 pg/mL.

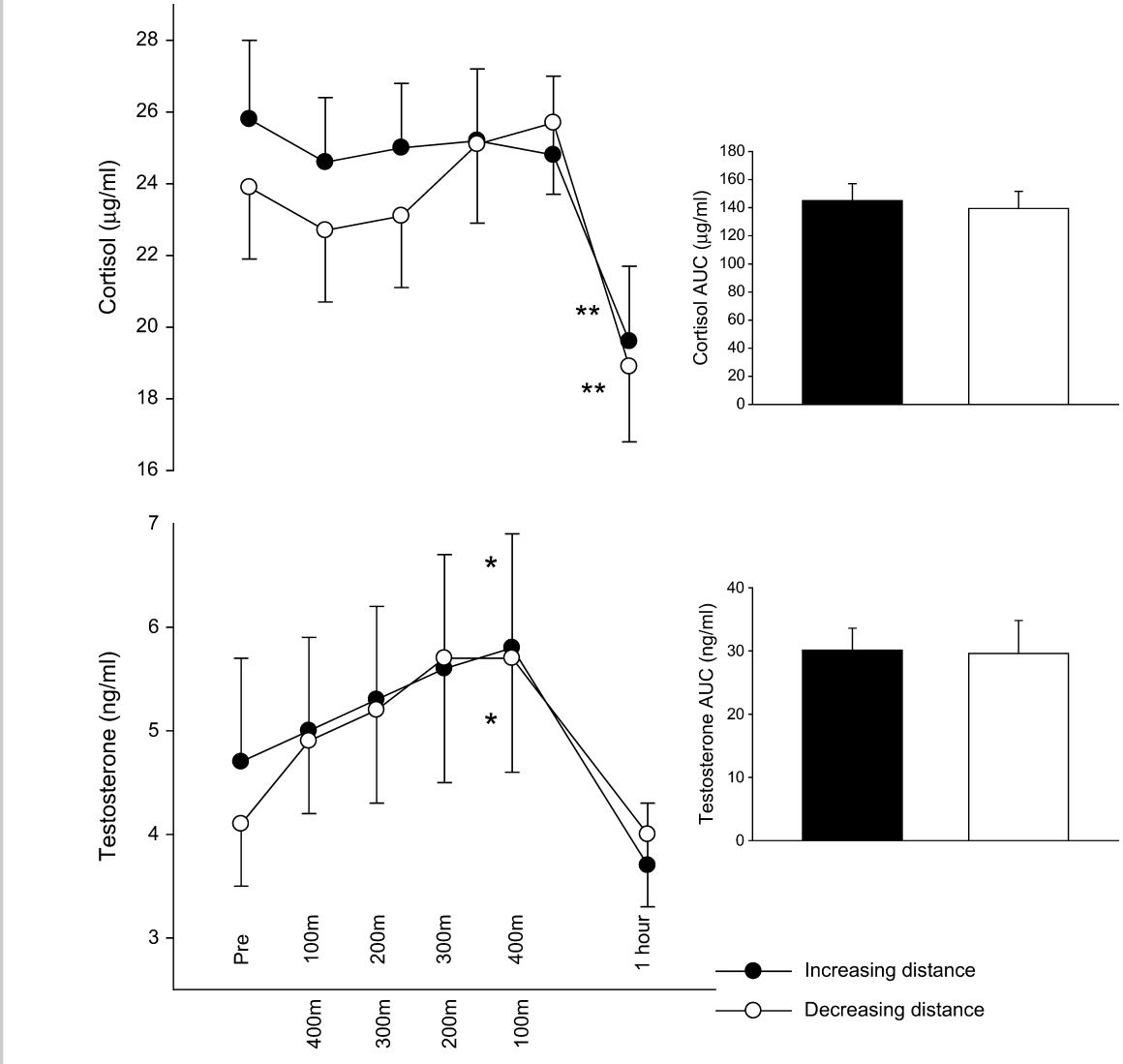

Figure 4. The effect of increasing and decreasing distance sprint interval on cortisol and testosterone levels. Both types of interval sessions were associated with a significant increase of circulating testosterone (*$p < 0.05$). After recovery, cortisol levels decreased to a below baseline level (**$p < 0.05$). There were no differences in the AUC of both mediators (right Panel).

Rate of Perceived Exertion. RPE was determined using the Borg scale (23) after each run during the increasing distance and decreasing distance sprint interval session, and the average RPE for each training session was calculated.

Statistical Analyses

A trial by time and a trial by distance ANOVA with repeated measurements were used to assess the difference between the 2 trials on lactate, circulating components of the GH-IGF-I

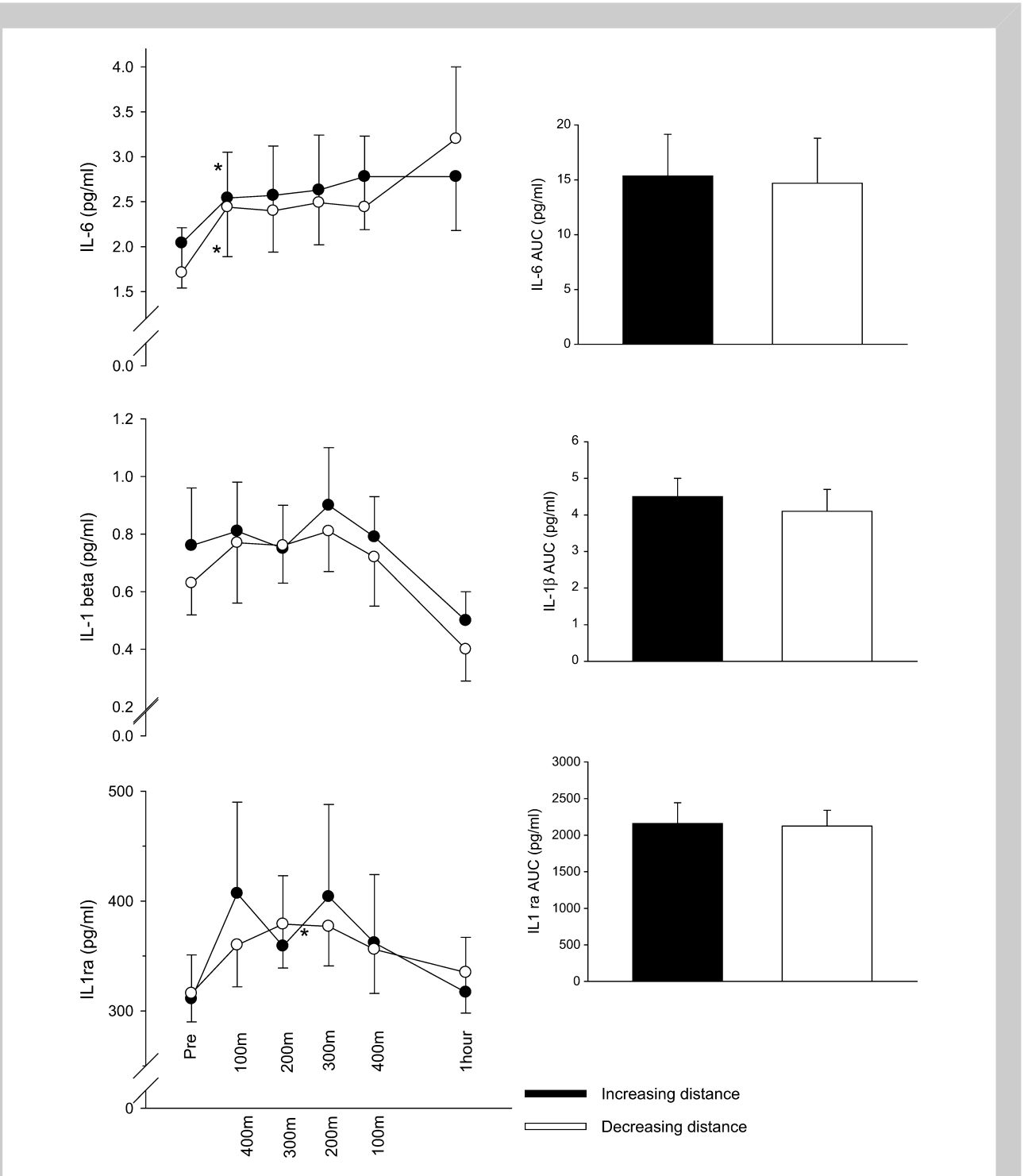

Figure 5. The effect of increasing and decreasing sprint interval on circulating pro and anti-inflammatory cytokines. Both types of interval sessions were associated with a significant increase in IL-6. Downhill interval exercise was associated with a significant increase in IL-1β and IL1ra levels (*$p < 0.05$).

axis, cortisol, and inflammatory mediators. In addition, we calculated and compared using paired *t* test the area under the curve for both training types. Data are presented as mean ± *SEM*. Significance was taken at $p \leq 0.05$.

Results

Trial by Time Assessment

The effect of the sprint interval exercise on lactate, anabolic, and catabolic hormones is summarized in Figures 2, 3, and 4. Both types of exercise sessions were associated with a significant increase in lactate, GH, IGF-I, IGFBP-3, and testosterone levels. Levels returned to baseline values during recovery. There were no significant changes in cortisol and IGFBP-1 levels.

Both types of exercise training sessions were associated with a significant increase in IL-6, IL-1, and IL1ra levels. IL-6 level remained elevated 1 hour after the end of exercise (Figure 5).

Trial by Distance Assessment

The only significant differences between the 2 trials were the increases in lactate in the 100 m, 200 m, and 300 m runs, greater increases in GH levels in the 100 m and 200 m runs, and a greater increase in testosterone levels in the 100 m run in the decreasing distance protocol.

There was a significant increase in IGFBP-1 levels 1 hour after the interval training, only in the decreasing distance group (from 15.4 ± 4.9 to 28.0 ± 6.1 ng/mL, $p < 0.05$). This increase was not statistically different from the change in the decreasing distance session (19.6 ± 3.5 to 25.5 ± 4.6, NS).

The average RPE during the increasing distance interval session was 13.0 ± 3.2 compared with 11.4 ± 3.1 during the decreasing distance interval session ($p = 0.07$).

Calculation of Area Under the Curve

Area under the curve was significantly greater only for lactate and GH in the decreasing distance protocol (Figures 2 and 3).

Discussion

Sprint interval training is one of the most commonly used training methods in anaerobic-type sports (10). Usually, athletes and coaches use measurements of heart rate or serum lactate during the exercise task to assess training intensity (6). However, although these measures may reflect exercise intensity (as also seen in the present study), their ability to evaluate the anabolic and/or catabolic effects of training is limited. In the present study, we determined the effect of different styles of brief sprint interval exercise sessions (with total exercise duration of less than 3 minutes each) on anabolic and catabolic hormones and circulating pro-inflammatory and anti-inflammatory mediators. Exercise was associated with a significant increase in GH, IGF-I, IGFBP-3, and testosterone in both types of interval sessions suggesting that the exercise led to an anabolic-type hormonal response. In addition, both interval exercise sessions led to a significant increase in the pro- and anti-inflammatory cytokines IL-6, IL-1, and IL1ra. Levels of IL-6 remained significantly elevated during the recovery period. Calculations of area under the curve indicated that lactate and GH levels were significantly greater in the decreasing distance exercise session. Rating of perceived exertion was higher in the increasing distance protocol, although this difference was not statistically significant ($p = 0.07$). These results suggest that despite the fact that running distance, running speed, and rest periods were similar in both training protocols, the metabolic demands and the anabolic response to the decreasing distance protocol is significantly greater compared with the increasing distance protocol. These data should raise the awareness of coaches and athletes that different types of interval training lead to different metabolic demands and hormonal responses, and as a consequence to the need of adapting specific modes of recovery to each type of training.

Previous studies examined the effects of endurance-type exercise on the GH-IGF-I axis. These studies suggested that to stimulate GH secretion, the exercise input should be sufficient to cause a sizeable metabolic effect (eg, above the lactic anaerobic threshold) and that the exercise duration should be at least 10 minutes (5). The exercise-induced GH peak was thought to occur 25–30 minutes after the start of exercise irrespective of the exercise duration (3,19,24). Recently, we demonstrated that a significant increase in GH secretion may also occur after a brief sprint interval training (ie, 4 × 250 m) (12). In the present study, both *brief* anaerobic-type interval trainings led to a very rapid, remarkable, and significant increase in GH levels, with a significantly greater increase in the decreasing distance protocol. To try and understand the dynamics of the hormonal and inflammatory response, we collected blood samples after each run of the different interval trainings and after 1 hour of recovery. It is possible, however, that a higher exercise-related GH peak could have been detected, if blood samples were collected 25–30 minutes after the start of exercise.

Both interval sessions resulted in an increase of circulating IGF-I levels. IGF-I plays a central role in the exercise-induced muscle adaptation (1). These results are consistent with previous reports indicating that very short supramaximal exercise efforts (eg, 90 seconds) (21) lead to an increase in IGF-I levels, and that IGF-I peaks after 10 minutes of endurance-type exercise (4,19). However, significant increases of IGF-I levels were not seen after brief, constant distance, interval training (4 × 250 m). Therefore, it is suggested that IGF-I may also play an important role in the muscle adaptation to anaerobic interval training and that the IGF-I response depends on the specific type and intensity of the interval training.

We also measured the effects of the exercise on IGF-I–binding proteins 1 and 3. The bulk of IGF-I is bound to binding proteins, the most important among them is binding protein 3 because it binds more than 95% of circulating IGF-I (18). Interestingly, some of these IGFBPs, like IGFBP-3, stimulate

IGF-I bioactivity, whereas others, like IGFBP-1, inhibit its anabolic effects. Therefore, our finding of increased exercise-associated IGFBP-3 in both the increasing and decreasing interval sessions, suggests an anabolic effect of exercise. In contrast, only the decreasing distance interval session was associated with an increase of the inhibitory binding protein, IGFBP-1. This suggests that despite the fact that running distance, running speed, and resting periods were similar in both training regimens, the decreasing distance interval session led not only to anabolic-type adaptations but also to responses that inhibit anabolic effects. The results support the notion that exercise-related effects on IGF-I are not mediated only through alteration of the amount of IGF-I per se but rather by the effect on its binding proteins as well.

The mechanism for the increase in IGF-I and IGFBP-3 is not clear (9). Although IGF-I and IGFBP-3 synthesis is GH-dependent, both GH, IGF-I and IGFBP-3 peaked at the same time, indicating that a GH-mediated increase of IGF-I and IGFBP-3 is unlikely (Figure 2). We can only speculate that the increase in IGF-I and IGFBP-3 resulted from a release from a more available pool or due to an increase in IGF-binding proteins proteolytic activity (14,19).

Both sprint interval sessions were associated with a significant increase in testosterone levels. A trial by distance analysis revealed that the increase in testosterone was higher in the 100 m in the decreasing distance session. Changes in testosterone levels are used frequently as an indicator of the anabolic-catabolic balance to determine the physiological strain of training (8,23). Therefore, its increase after both sprint interval exercise sessions may suggest anabolic adaptations. Interestingly, the exercise-related testosterone peak paralleled the peaks of the anabolic GH-IGF-I axis factors (ie, GH, IGF-I, and IGFBP-3).

Both interval sessions led to a significant increase in the pro-inflammatory and anti-inflammatory cytokines IL-1, IL-6, and IL1ra. Levels of IL-6 remained significantly elevated during the recovery period in both sessions.

The major source for the exercise-related IL-6 increase is the skeletal muscle (17,22). IL-6 increases during exercise both with and without evidence of muscle damage. However, IL-6 is believed to play an important mediatory role in the inflammatory response needed for postexercise-associated muscle damage repair (20). It is not so surprising, therefore, why in contrast to all other marker that returned to baseline levels during the recovery, levels of IL-6 remained elevated during the recovery period of both interval protocols.

In addition, it was previously demonstrated that inflammatory mediators (in particularly IL-6) might alter IGF-I activity through a variety of mechanisms including direct inhibition of IGF-I production (7). Therefore, it is possible that increases of interleukin-1 beta and IL-1ra and the prolonged exercise-related increase in IL-6 in both interval sessions may counter balance the anabolic effect of these trainings on the GH-IGF-I axis.

Finally, consistent with a previous report (13), despite the higher metabolic demand and pronounced anabolic responses (higher lactate and GH area under the curve levels) during the decreasing distance interval protocol, RPE was higher in the increasing distance interval protocol (although this difference only approached statistical significance). When the athletes were asked to explain why the increasing distance training protocol was perceived as more intense, they replied that the fact that the longest and hardest run (ie, 400 m) was only at the end of the session, was very difficult to tolerate. This interesting finding suggests that physiological and psychological features do not always parallel during competitive sport training, and that coaches should be aware of these possible differences and their consequences to the training and recovery process.

Practical Applications

Changes in the anabolic-catabolic hormonal balance, and in the circulating inflammatory cytokines were found after increasing and decreasing distance brief sprint interval exercise training indicating that these markers may be used to gauge the training intensity of different anaerobic-type exercise. Changes in the GH-IGF-I axis and testosterone suggested mainly exercise-related anabolic adaptations to both interval sessions. Increases of inflammatory mediators in both interval sessions suggest an important role for these substances in muscle tissue repair after anaerobic exercise. Decreasing distance interval training was associated with a greater metabolic (ie, lactate level) and anabolic response (as reflected by a greater increase of GH level). Interestingly, these greater metabolic and anabolic responses were not accompanied by an increase in RPE, suggesting that physiological and psychological responses to interval training do not necessarily correlate. Coaches and athletes should be aware of these differences, and as a consequence, of the need for specific recovery adaptations after different types of interval training sessions. Differences in physiological and psychological responses to competitive sport training, and their influence on the training course and recovery process, should also be addressed. The use of hormonal and inflammatory markers in the assessment of longer periods of anaerobic-type training is yet to be explored.

Acknowledgments

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