

PEAK CORTISOL RESPONSE TO EXHAUSTING EXERCISE: EFFECT OF BLOOD SAMPLING SCHEDULE

W. Daly, C. Seegers, S. Timmerman, A.C. Hackney

Endocrine Section - Applied Physiology Laboratory, University of North Carolina, Chapel Hill, North Carolina, USA

Abstract

Introduction: Strenuous exercise provokes increases in circulating cortisol levels. When the peak cortisol response to exercise occurs is a point of contention, as some research suggests the peak response coincides with the end of exercise while other indicate it is delayed and occurs during recovery.

Aim of the study: This study examined when peak cortisol levels occur in response to intensive, exhausting exercise of a prolonged nature.

Methods: Thirty-four healthy male subjects ran on a treadmill until volitional exhaustion. Blood specimens were analyzed for cortisol levels immediately at the end of exercise and at 30, 60, and 90 minutes into recovery.

Results: A significantly greater number (25/34; i.e., 73.5%) of the peak cortisol responses occurred during the recovery period (at 30 – 90 minutes) after the subjects reached volitional exhaustion and had stopped exercising.

Conclusion: The findings suggest that if researchers are interested in assessing the peak cortisol response to exhausting exercise they should continue blood sampling for approximately 1 hour into the recovery period.

Key words: endocrines, hormones, recovery, stress

Introduction

Cortisol is a hormone involved with numerous physiological processes. It is released from the adrenal cortex in response to either physiological or psychological stress. Its actions are widespread, and while primarily involved with metabolism, cortisol can also affect the kidneys and immune function (1).

Physical activity can stimulate the adrenal cortex to release cortisol (2). The response is relatively proportional to the intensity of the work being performed once an individual's threshold for response (~50-60% of maximal aerobic capacity) is re-

ached (3). At the end of maximal, exhaustive exercise, it is not uncommon for cortisol levels to be 30-50% higher than basal resting levels (4, 5). Moreover, if exercise is performed at sub-maximal levels for prolonged periods of time cortisol can ultimately become elevated to near maximal levels (6, 7, 8).

For decades our laboratory has measured cortisol during a variety of research protocols. On several occasions we have observed that peak cortisol response occurs during the recover period, after exercise has stopped. While previous researchers have reported this as a secondary finding (3, 9),

we are presently unaware of research work that specifically addressed this topic with a scientific investigation to determine the timing of peak responses following activity. Thus, the aim of this study was to examine when peak cortisol levels occur in response to intensive, exhausting exercise of a prolonged nature.

Methods

Highly trained male endurance athletes volunteered to participate in this study ($n=34$). The subjects were in excellent physical condition with no health abnormalities or illnesses relating to the endocrine, musculoskeletal, or cardiopulmonary systems. All had been participating in endurance type training for a minimum of 5 days a week for the last 2 years. Prior to participation, the subjects signed a "Consent to Act as a Human Subject" form as approved for use by the Academic Affairs Institutional Review Board at The University of North Carolina.

Subjects reported to our laboratory for two separate experimental sessions. At the first session, subjects completed an informed consent waiver, a medical history form, a training log, and underwent a physical screening to insure ability to participate in this study. After body height (cm) and body mass (kg) measurements were taken, subjects underwent a modified Åstrand maximal treadmill test (as reported by reference 10) to determine maximal oxygen consumption ($\dot{V}O_{2\max}$). Respiratory gases were collected continuously throughout exercise using an open-circuit spirometry system (Parvo Medics, UT). The following criteria were used to determine subjects attainment of $\dot{V}O_{2\max}$: $\dot{V}O_2$ did not increase by more than $0.15 \text{ L}\cdot\text{min}^{-1}$ despite an increase in workload, heart rate failed to increase despite an increase in workload, and subject's rating of perceived exertion (RPE) was >17 (11, 12). From

the respiratory gas data collected during the maximal treadmill test, each subject's ventilatory threshold (VT) was calculated using the criteria of Wasserman (13).

The second experimental session required subjects to report to the laboratory between 1300 and 1500 hours in a 2.5-hours fasted state having abstained from strenuous activity, alcohol, and sex activity for the 24-hours prior to this session and caffeine for the 12 hours immediately prior to it. Once in the laboratory, subjects' body height, body mass, and body composition (skin folds at the chest, abdomen, and thigh; [14]) measurements were taken before beginning a 30-minute rest in the supine position. At the beginning of the rest, an indwelling 20-gauge catheter was placed into the antecubital vein (kept patent via saline infusion), and a Polar® heart rate monitor was fixed around the subject's chest. At the end of the 30-minute rest, a baseline blood sample was taken. Subjects were then allowed five minutes to actively warm-up and stretch. At the end of the five minutes, subjects began the prolonged exercise run on the treadmill until they reached volitional exhaustion (VEx). The running speed was set to correspond to approximately 100% of their VT ($\pm 3\%$) intensity. During the run to VEx, select physiological data were monitored throughout. At the point in which subjects' indicated VEx, investigators provided strong verbal encouragement. This was done to motivate the subjects and ensure subjects did not stop exercise until they were truly exhausted. At the point of VEx a second blood sample was immediately taken (Impost). Subjects were then allowed a five minute active cool-down before resting in a supine position throughout a 90-minute recovery period. Additional blood samples were taken at 30 (30min), 60 (60min), and 90 minutes (90min) into recovery.

All blood samples were drawn into EDTA treated vacutainer tubes and placed on ice until processing. These were later centrifuged at 4°C for 15 minutes at 3000 X g (Centra-8R IEC, MA). Separated plasma was stored frozen at -80°C until hormonal analysis. Levels of cortisol were determined using standard single antibody solid phase radioimmunoassay (RIA) kits (DPC Inc. Los Angeles, CA). All assay performance characteristics were within acceptable limits as the within and between assay coefficients of variation were less than 10%.

A non-parametric Chi-Square analysis was used to determine differences between frequencies of peak cortisol responses occurring at Impost and the recovery measurement time points. Additionally, parametric repeated measures ANOVA followed by a Bonferroni post hoc test was used to determine if the cortisol responses to exercise was significantly different from basal resting levels.

Results and Discussion

The physical characteristics of the subjects were: body height = 180.0 ± 5.9 cm, body mass = 74.1 ± 6.6 kg, age = 24.5 ± 4.6 yr, and body fat 12.1 ± 5.0 % ($X \pm SD$). The mean running time until exhaustion was 82.24 min (± 16.9 min). Exercise caused a significant elevation in the cortisol levels ($p < 0.001$), as the mean values found at Impost through 90min recovery were all greater than baseline resting levels. The cortisol responses of the individual subjects are depicted in Figure 1.

The number of subjects displaying a peak cortisol response at Impost was 9, at 30min recovery was 21, at 60min recovery was 3, and 90min recovery was 1. Statistical analysis revealed that the frequency of peak responses appearing at Impost and 30min recovery was significantly greater than at 60min and 90min of recovery ($p < 0.05$). The Impost and 30min frequencies also differed from one another; but the 60min and 90min frequencies did not.

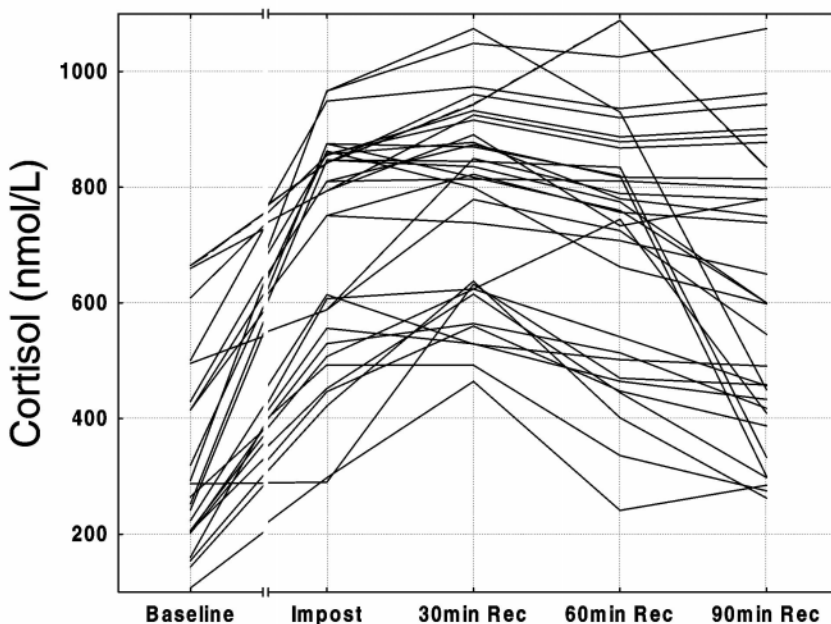


Fig. 1. Each line represents an individual subject response for cortisol. The running time until each subject reached exhaustion was variable; thus, a break appears in the X-axis between the Baseline and Impost time points.

The intent of this study was to examine when the peak cortisol levels occur in response to exhausting exercise. Our results suggest that in highly trained subjects, peak cortisol responses do not always occur at the point of exercise exhaustion. In fact, 73.5% of our peak responses (25/34) occurred during recovery after subjects reached volitional exhaustion and had stopped exercising.

The principle stimuli to increase cortisol production involves anterior pituitary released adrenocorticotrophic hormone (ACTH), sympathetic input from preganglionic cholinergic fibers and circulating IL-6 levels (muscle source) (1, 15). We did not measure circulating ACTH, IL-6, or any index of sympathetic nervous activity. However, our purpose was not to determine what was the mechanism of cortisol response but rather what was that peak response and when did it occur.

To conclude, the present findings suggest that if researchers are interested in assessing the peak cortisol response to exhausting exercise they should continue blood sampling for at least approximately 1 hour into recovery. Furthermore, these data also illustrate the concept of individual variance in physiological responses. That is, even when measures are taken to control confounding influences and to equate levels of exercise stress, subjects can still respond differently. Researchers working in the area of exercise endocrinology should take these findings into consideration when designing experimental studies to assess peak cortisol responses.

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Address for correspondence:

Dr. A.C. Hackney

Applied Physiology Laboratory

University of North Carolina

Chapel Hill, North Carolina USA

27599-8700

Email: thackney@med.unc.edu