Short communication

The effect of air scuba dives up to a depth of 30 metres on serum cortisol in male divers

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Abstract

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Introduction: Environmental pressure changes with depth may lead to changes in various hormone levels in the body. Of interest are the so-called stress hormones, such as cortisol. Other factors altering cortisol levels are anxiety, exercise and cold. We investigated serum cortisol changes after air scuba dives in 24–27^{O}C open water up to a depth of 30 metres.

Method: Ten, experienced, male divers participated in the study. Four dives, to depths of 1, 10, 20 and 30 metres' sea water (msw) for 20 minutes bottom time, at rest, were conducted at about 1000 h on four consecutive days in the Persian Gulf. Before diving and soon after surfacing, approximately 5 ml blood was drawn from a right antecubital vein for serum cortisol assay, using a radioactive immunoassay technique. Repeated measures was used to analyse cortisol changes with depth.

Results: There were significant differences in the pre-dive cortisol levels ($df = 1$, $F = 5.978$, $P < 0.037$) and post-dive levels ($df = 1$, $F = 34.567$, $P < 0.001$). Cortisol levels increased with immersion irrespective of depth compared to pre-dive levels, whilst they were further significantly raised after dives to 10 m (mean 312.6 nmol·L^{-1}), 20 m (mean 299.1 nmol·L^{-1}) and 30 m (mean 406.7 nmol·L^{-1}) depth compared to levels after the 1 m dive (mean 189 nmol.L^{-1}).

Conclusion: The observed changes in serum cortisol were considered to be the result of the physiological effects of immersion combined with increased environmental pressure, rather than resulting from anxiety, heavy exercise or cold stress.

Key words

Scuba diving, physiology, endocrinology, diving research

Introduction

Many individuals, whether for recreational or professional reasons, are involved with the underwater world and its challenges. Environmental pressure changes with depth, and such changes may lead to changes in various hormone and enzyme levels in the body. Of particular interest are the so-called stress hormones, such as cortisol, regarded as the most important glucocorticoid in humans.[1] Cortisol levels demonstrate diurnal variation, highest levels occurring at about 0600 to 0800 h and lowest levels at about midnight. Normal values for a blood sample taken at 0800 h vary between 165.5 and 634.5 nmol·L^{-1}.[2] Reports suggest that plasma or salivary cortisol levels fall during dry-chamber pressure exposures but rise after open-water dives.[3,4] Given the physiological importance of cortisol, we measured serum cortisol levels before and after open-water air dives to depths up to 30 metres' sea water (msw).

Methods

SUBJECTS

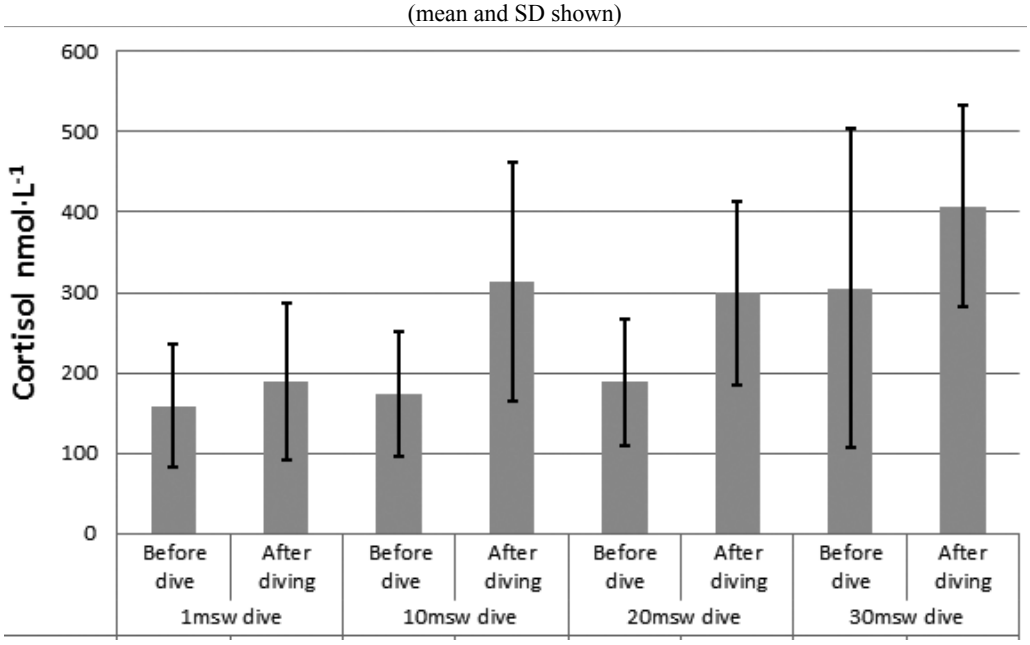
The study was approved by the Department of Physical Education, Science and Research Branch, Islamic Azad University, Fars, Iran. Twelve, experienced, male divers certified to dive up to 30 msw depth were recruited for the study. Two subjects were subsequently excluded because of illness during the project. The divers gave informed consent and completed a medical questionnaire. Age, height and weight were measured, and body mass index (BMI) calculated.

PROCEDURE

Four dives were conducted on four consecutive days off Qeshm Island in the Persian Gulf, with a water temperature of 24 +/- 2^{O}C and on sunny days with an air temperature of 27 +/-2^{O}C. The divers wore 3-mm-thick wetsuits. All dives were performed at about 1000 h. The four dives were to depths of 1, 10, 20 and 30 msw for 20 minutes bottom time. The divers remained at rest, kneeling on the sea floor throughout the time at depth. The dive order was not randomised.

Before diving, approximately 5 ml of blood was drawn from a right antecubital fossa vein into a plain sample tube. Upon surfacing at the end of the dive, a second blood sample was drawn. All pre- and post-dive blood samples were taken to a modern laboratory in Shiraz and centrifuged at 3,200 rpm and the serum separated and stored at -25 ^{O}C for measurement the following day. Cortisol was measured using Cortisol Radioimmunoassay Kit IM 1841, (Czech Beckman Coulter Company).

Figure 1
Changes in serum cortisol (nmol·L^{-1}) before and after 20-minute dives to depths of 1, 10, 20 and 30 metres' sea water (msw) (mean and SD shown)



STATISTICAL METHODS

A repeated measures ANOVA was used to analyse cortisol changes with depth. If sphericity was not assumed, a Greenhouse-Geisser correction was applied. If a significant difference was observed, paired Student's *t*-tests were used to analyse specific differences. All data are reported as the mean and standard deviation (SD). Significance was assumed at the $P \leq 0.025$ level after applying a Bonferroni correction for multiple comparisons. The software package SPSS 22 was used.

Results

The 10 divers studied had a mean age of 28 years (range 19–39), mean height 178 cm (range 173–184), mean weight 84 kg (range 72–96) and BMI 27 kg·m^{-2} (range 23–30). Pre- and post-dive cortisol levels are shown in Figure 1. The differences in the pre-dive cortisol levels (1 msw, mean 158.36 (76.6) nmol·L^{-1}; 10 msw, mean 173.8 (78.5) nmol·L^{-1}; 20 msw, mean 188.2 (78.4) nmol·L^{-1}, and at 30 msw, mean 305.4 (199.1) nmol·L^{-1}) did not reach statistical significance after a Bonferroni correction (df = 1, F = 5.978, $P < 0.037$). There were significant differences between the pre-dive cortisol levels (df = 1, F = 5.978, $P < 0.037$) and post-dive levels (df :1 , F = 34.6, $P < 0.001$) at each depth. Cortisol levels increased with immersion, irrespective of depth, compared to pre-dive levels, whilst they were raised further significantly after dives to 10 msw (mean 312.6 (SD 148.8) nmol·L^{-1}; 20 msw (mean 299.1 (114.5) nmol·L^{-1} and 30 msw (mean 406.7 (125.4) nmol·L^{-1} compared to 1 msw (mean 189 (97.8) nmol·L^{-1}).

Discussion

In a study of the effects of increased pressure, variations in inspired gases and the use of a mask during dry chamber dives on salivary cortisol in professional divers, levels decreased from a mean of 16.0 mmol·L^{-1} pre-dive to 10.3 mmol·L^{-1} post-dive ($P < 0.01$).[3] Cortisol values did not relate to the anthropometric and physical fitness characteristics of the divers or to increased pressure, variation in inspired gases or the use of a mask. The individual variation in cortisol values was large. In another dry chamber study, eight professional divers were exposed to air or 100% oxygen at 253 kPa for 60 min. As in the first study, cortisol levels decreased significantly ($P = 0.001$) during the dry dives.[5] During a hyperbaric saturation dive to 4.1 MPa in six subjects, salivary cortisol concentration did not change throughout the dive.[6]

In a 1972 study, plasma cortisol levels in dry-suited divers before and after 1 or 30 msw dives in cold (12^{O}C) water were significantly elevated compared to control values.[7] The rise was twice as great with the 30 msw dives (+42%) compared to 1 msw (+23%). Levels before 30-metre dives were 25% higher than before 1-metre dives, and all values were approximately twice those seen in the present study. These changes were attributed to anxiety over deep open-water diving in a 'stressful' diving situation.

In other studies, salivary cortisol levels in trainee scuba divers showed significant increases before a swimming-pool training session and before an open-water dive compared to control values.[4] During prolonged whole-body immersion in cold water, cortisol demonstrated a marked diurnal variation,

with large increases occurring after 2200 h.[8] Increased levels of cortisol have also been shown in divers exposed to an underwater navigation stress.[9]

In the present study, serum cortisol increased progressively with dives of increasing depth over the depth range of 1 msw to 30 msw. Psychological stress and anxiety are known to increase serum cortisol. There is evidence that individuals who are characterised by elevated levels of trait anxiety are more likely to have greater state anxiety responses when exposed to a stressor, and hence, this sub-group of the diving population is at an increased level of risk.[10] Divers with an elevated level of anxiety and poor coping are at higher risk of developing panic reactions than those possessing more adequate stress-coping mechanisms.[11] However, we did not assess our divers for their trait anxiety levels. Since the divers who participated were experienced, professional divers, it does not seem likely that anxiety was the main factor behind these increases.

Exercise is a factor changing cortisol. Variations in free cortisol concentrations associated with a treadmill test to exhaustion and high-level competition have been studied in top-level swimmers.[12] Salivary cortisol was measured 30 minutes before and 15 minutes after competition and was compared with concentrations obtained at the same times of the day before and after the treadmill tests and during a rest day. Cortisol levels were significantly higher before and after competition than before and after a treadmill test. In endurance athletes, cortisol is increased significantly in both serum and saliva in response to high-intensity exercise.[13] Since the divers in the present study were at rest during the dives, it is unlikely that physical activity was the main factor behind the increases that we observed.

Cold is a well-recognised factor changing cortisol. Prolonged whole-body immersion in cold water results in elevated plasma cortisol levels.[8] The temperature of the water in the present study was warm, but slightly less (24 ± 2^{O}C) at 30 msw depth than at the surface (27 ± 2^{O}C). As all divers were wearing 3-mm-thick wetsuits and none showed any signs of coldness, it does not seem that cold was the main factor behind these changes. However, body core temperature was not measured.

We conclude that the changes in serum cortisol observed were predominantly the result of the physiological effects of immersion combined with increased environmental pressure.

References

1 Scott E. *Cortisol and stress: how to stay healthy*. Available from: http://about.com. (last accessed 29 November 2011).

2 Stewart PM, Krone NP. The adrenal cortex. In: Kronenberg HM, Melmed S, Polonsky KS, Larsen PR, editors. *Williams' textbook of endocrinology*, 12th ed. Philadelphia, PA: Saunders Elsevier; 2011: chap 15.

3 Tikkinen J, Hirvonen A, Parkkola K, Siimes MA. The effects of increased pressure, variation in inspired gases and the use of a mask during dry chamber dives on salivary cortisol in professional divers . *Diving Hyperb Med*. 2011;41:211-5.

4 Coetzee N. Measurement of heart rate variability and salivary cortisol levels in beginner scuba divers. *African Journal for Physical, Health Education, Recreation and Dance*. 2011;17:729-41.

5 Lund V, Kentala E, Scheinin H, Klossner J, Koskinen P, Jalonen J. Effect of hyperbaric conditions on plasma stress hormone levels and endothelin-1. *Undersea Hyperb Med*. 1999;26:87-92.

6 Hirayanagi K, Nakabayashi K, Okonogi K, Ohiwa H. Autonomic nervous activity and stress hormones induced by hyperbaric saturation diving. *Undersea Hyperb Med*. 2003;30:47-55.

7 Davis FM, Charlier R, Saumarez R, Müller V. Some physiological responses to the stress of aqualung diving. *Aerospace Med*. 1972;43:1083-8.

8 Smith DJ, Deuster PA, Ryan CJ, Doubt TJ. Prolonged whole body immersion in cold water: hormonal and metabolic changes . *Undersea Biomedical Research*. 1990;17:139-47.

9 Morgan CA, Rasmusson A, Pietrzak RH, Coric V, Southwick SM. Relationships among plasma dehydroepiandrosterone and dehydroepiandrosteronesulfate, cortisol, symptoms of dissociation, and objective performance in humans exposed to underwater navigation stress. *Biological Psychiatry*. 2009;66:334-40.

10 Morgan WP. Anxiety and panic in recreational scuba divers . *Sports Medicine*. 1995;20:398-421.

11 Anegg U, G Dietmaierb, A Maiera, F Tomasellia, S Gabora, K.W Kallusc, F.M Smolle-Jüttnerl. Stress-induced hormonal and mood responses in scuba divers: a field study. *Life Sciences*. 2002;70:2721-34.

12 Aubets J, Seggura J. Salivary cortisol as a marker of competition related stress. *Science et Sports*. 1995;1Q:149-54.

13 Van Bruggen MD, Hackney AC, McMurray RG, Ondrak KS. The relationship between serum and salivary cortisol levels in response to different intensities of exercise. *Int J Sports Physiol Perform*. 2011;6:396-407.

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