Hyperbaric stress in divers and non-divers: Neuroendocrine and psychomotor responses

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ABSTRACT

This study compared neuroendocrine and psychomotor responses in divers (D, n=11) and non-divers (ND, n=9) following 30-minute hyperbaric and decompression stress to 180, 300 and 450 kPa. Venous blood was drawn pre-dive and at 20 and 60 minutes post-dive and analyzed for norepinephrine (NE), epinephrine (E), tryptophan (TRP), cortisol (COR), growth hormone (GH), adrenocorticotrophic hormone (ACTH) and prolactin (PRL). Reaction time was assessed using a psychomotor vigilance task. There was no difference between groups, across time or among levels of hyperbaric stress, for NE, E, TRP or GH. Small decreases over time in COR were noted. ACTH was significantly higher for ND at 20 minutes following 180 kPa and after 60 minutes for 450 kPa exposure. PRL increased significantly more for ND, and changes from baseline following 450 kPa exposure were moderately related (r=0.52) to the significant slowing of reaction time at 20 minutes (296 ± 55 msec) and 60 minutes (277 ± 35 msec) compared with baseline (247 ± 22 msec), although PRL returned to baseline levels faster than reaction time. It was concluded that for the stress hormones measured, PRL may provide some indication of the adaptation involved with repeated hyperbaric stress, but its relationship to changes in reaction time was weak.

INTRODUCTION

Exposure to a hyperbaric environment together with the subsequent decompression involved with the return to normobaric conditions at the surface triggers the activation and release of hormones within the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic-adrenomedullary system (SAS) consistent with the general stress syndrome first described by Selye more than 60 years ago (1). The extent of the activation is dependent on several factors, including the severity of the stress (2) and the experience of the diver (3), implying that an adaptive response may occur through repeated exposure to the stress.

Acute hyperbaric exposure has been associated with a reduction in cognitive function, which for naive individuals exposed to pressures of 60 meters of sea water (msw) for 10 minutes were related to the changes observed for cortisol (COR), growth hormone (GH), testosterone, norepinephrine (NE) and epinephrine (E) (4). A slowing of visual reaction time and impairment in motor function that was proportional to the depth of immersion in professional divers has also been reported (5-7).

Recent neuroimaging studies have shown that elevated COR leads to deactivation of the hippocampus and a decrease in cognitive function (8), thereby providing a link between the activation of the HPA axis and cognitive performance. Interestingly, Davis *et al*. (2, 3) observed that the decrease in cognitive and motor function during a 30-msw dive compared with a 3-msw dive was related to the increase in COR levels at the greater depth.

Prolactin (PRL) is another stress hormone that has been suggested as a peripheral marker of impending central fatigue, given that serotonergic and dopaminergic neurons in the brainstem stimulate and inhibit PRL release, respectively (9-11). PRL has also been shown to increase during exposure to stressors such as exercise in the heat (12, 13), chemical pollutants (14), parachute jumping (15, 16) and surgery (17, 18). Increased brain serotonin has been linked to lethargy and decreased mood, motivation (11, 19), and CNS drive (20) that could impact on cognitive function. However, the role of PRL during exposure to hyperbaric and decompression stress has not been examined.

Repeated exposure to hyperbaric stress may be manifested in an altered release of neuroendocrine markers that is indicative of an adaptive response. Early attempts to characterize this adaptive response by neuroendocrine mediators focused on fluid and electrolyte balance, with repeated measurements before, during and after saturation exposures to varying degrees of increased pressure (21-23). Stress hormones such as COR, NE and E showed little change throughout the prolonged exposures. Mateev *et al*. (24) also reported little impact of saturation dives to varied depths in professional divers for COR, adrenocorticotrophic hormone (ACTH) or GH. At greater saturation depths, increases in plasma NE have been observed (25). However, to our knowledge, no attempt was made to relate any of the changes in these neuroendocrine markers to any change in psychomotor performance.

Few, if any, studies have attempted to relate the severity of hyperbaric and decompression stress to the magnitude of the neuroendocrine strain and to compare this relationship between groups characterized as being either naive or experienced to hyperbaric and decompression stress. Further, although studies have shown impairment in psychomotor performance during hyperbaric stress in non-divers or experienced divers (4-7), studies have not examined whether the response to a given level of hyperbaric stress differs with the level of experience. In the present study, a cross-sectional rather than a longitudinal design was used to examine the adaptive neuroendocrine and psychomotor responses to varied levels of hyperbaric and decompression stress. It was hypothesized that the activation of the HPA axis and SAS would be reduced following exposure to any given level of hyperbaric and decompression stress in a group of experienced divers compared with non-divers who had never been exposed to the stress. Further, it was hypothesized that the disruption in psychomotor function following the hyperbaric and decompression stress would be greater among non-divers as the severity of hyperbaric and decompression stress increased and that these changes would be related to differences in neuroendocrine markers within the HPA axis and SAS.

METHODS

All trials were conducted within the hyperbaric facility at Defence Research and Development Canada (DRDC) – Toronto following approval from the human research ethics committee of DRDC. Subjects were medically screened with a 12-lead electrocardiogram, chest X-ray and physical exam, and a full explanation of procedures, discomforts and risks was given prior to obtaining written informed consent. Twenty males volunteered to participate in the study. Respective mean values and SD for age, height and weight were 38.9 ± 8.4 y, 1.76 ± 0.07 m and 83.0 ± 13.2 kg.

Classification of groups

Subjects were recruited and classified as being either non-divers (ND, n = 9) having never experienced hyperbaric stress, or experienced divers (D, n = 11) having been exposed at least once per month during the previous six months to hyperbaric and decompression stress. Nine of the subjects in this group were professional military divers, who were classified as explosive ordnance disposal divers and posted to DRDC-Toronto, while the others were recreational divers. There were no differences between groups in the descriptive characteristics listed above.

Experimental design

For all hyperbaric exposures, subjects breathed chamber air and wore a Durrette® coverall over personal underwear and static-control chamber shoes over personal socks. A minimum of 14 days prior to the first experimental session subjects completed a familiarization exposure to 90 kPa for 15 minutes experiencing all of the instrumentation and testing described below. The three experimental sessions involved 30 minutes of exposure to 180, 300 or 450 kPa, which were defined as low, moderate or high levels of hyperbaric stress, respectively.

Pressurization rates were 18 kPa·min^{-1}, and decompression rates were in accordance with established dive tables[1] and represented 1, 15 and 55 minutes for the low, moderate and high levels of hyperbaric stress. Experimental sessions were separated by at least six to seven days, with the order of presentation standard for all subjects, from the lowest through the highest level of stress. The presentation order was standardized to help reduce the risk of decompression illness for the non-divers, who had no prior history of exposure to hyperbaric and decompression stress. Testing commenced in the morning around 08:00 a.m. for all sessions.

Measurements

A 20-guage catheter (BD Insyte™ Autoguard™, 20GA, Utah) was inserted into an antecubital vein and flushed with sterile saline to maintain patency. Subjects then remained seated for 30 minutes before a 20-mL baseline blood sample (Pre) was taken. Additional 20-mL blood samples were taken at 20 (P20) and 60 minutes (P60) after surfacing from the hyperbaric exposures. Aliquots of blood were transferred to untreated and EDTA-treated vacutainers. Untreated blood sat to clot for 20 minutes before centrifugation at 2800 rpm for 15 minutes at 4°C, whereas the blood in EDTA tubes was mixed by inversion and centrifuged immediately. Respective serum and plasma aliquots were frozen at -20°C, and then stored at -80°C until subsequent analyses.

[1] 1992, Table 1 (Metres), DCIEM Diving Manual. Air decompression procedures and tables. DCIEM No. 86-R-35, Universal Dive Techtronics, Inc., Richmond, British Columbia.

PRL, GH, COR and ACTH were determined by Chemiluminescent Immunoassay (Diagnostic Products Corporation®, IMMULITE®, Inter Medico, Canada). The GH and PRL IMMULITE® are a solid-phase, two-site sequential assay; the COR IMMULITE®, a solid-phase, competitive enzyme assay; and the ACTH IMMULITE®, a solid-phase, two-site sequential assay. The analytical sensitivity was PRL ± 0.5 μg·L^{-1}, GH ± 0.01 μg·L^{-1}, COR ± 5.5 nmol·L^{-1} and ACTH ± 1.98 pmol·L^{-1}.

Plasma catecholamines (E and NE) were determined using negative ion chemical ionization gas chromatography/mass spectrometry (GC/MS), as described by Zamecnik (26). Plasma-free concentrations of tryptophan (TRP) were also determined by GC/MS analysis (EZ:faast™, Phenomenex, Torrance) Plasma samples (100μL) underwent a solid phase extraction, derivatization and a liquid/liquid extraction using Norvaline (0.2 mM) as the internal standard, prior to GC/MS analysis with an injection volume of 1.5-2 μL. The sensitivity of the EZ:faast reports limits of detection within 0.1-0.2 μmol·L^{-1}.

The psychomotor vigilance task (PVT) is a test of continuous vigilance, and it was performed immediately following each blood sampling time point. The task was comprised of the subject reacting to a visual cue, which appeared in the middle of a screen of a personal digital assistant (Palm Zire 21). The subject's task was to press a designated key as soon as possible after the visual cue appeared. The amount of time between each presentation of the cue was randomized between one and five seconds. The total time of the task was five minutes, with an average of 50 presentations per test session. The mean reaction time calculated for each session represents an average from all the presentations. The PVT has a fast learning curve of one to three trials (27), and subjects were provided with four practice trials during the familiarization session.

Venous gas emboli (VGE) were monitored prior (Pre) to all hyperbaric exposures to obtain a baseline recording of each subject's heart sounds and approximately 20, 40, 80 and 120 minutes post-arrival at the surface using Doppler ultrasonic bubble detectors (TSI DBM 9008, Techno Scientific Inc., Woodbridge,

Ontario, Canada). Each subject's left and right subclavian veins and precordium region were monitored at rest and with movement (fist squeeze and deep knee bend, respectively) as indicators of VGE activity in the upper limbs and cranial region, and whole body, respectively. Experienced Doppler technicians manually categorized the auditory output from the bubble detector using the Kisman-Masurel (K-M) code. The resultant K-M bubble grades of the VGE at rest were then converted into numerical values (28) to integrate the time distribution of bubble activity recorded during the entire 120-minute observation period. The resultant value, known as the Kisman Integrated Severity Score (KISS), assumed to be related to the volume of released inert gas, provides a more complete representation of overall bubble activity in terms of relative bubble load stress on the diver (29). Although all venous blood flows through the pulmonary artery, which was accessible to our Doppler probes at the precordial region, several investigators have noted reduced sensitivity to smaller bubbles in this region. For example, subclavian VGE signals, which are unambiguous due to low background noise, are frequently not detected over the precordium. Although VGE frequency at the different sites is highly correlated (30), we endeavoured to further minimize variation and enhance sensitivity by integrating KISS results at all three measuring sites. An algorithm for integrating scores has not yet been reported, so for the purposes of this study we summed the resting KISS results of the three sites, precordium, left subclavian and right subclavian, as the total KISS [tKISS; (31)].

Statistical analyses

An analysis of variance (ANOVA) with one between factor (group) and two within factors (pressure and time) was used for the various hormonal analyses described above and for the scores of the PVT. To correct for violations in the assumption of sphericity with the repeated factors, the Huynh-Feldt correction was applied to the F-ratio. When a significant F-ratio was obtained, post-hoc analyses utilized a Newman-Keuls procedure to isolate differences among the treatment means. All ANOVAs were performed using statistical software (SuperAnova V.1.11 (1991), Abacus Concepts, Inc). For all statistical analyses, an alpha level of 0.05 was used. Data are presented as mean values ± SD.

Results

VGE were detected in one diver in D and one subject in ND following decompression from the 30-minute dive to 180 kPa, four of D and three of ND following the 300-kPa dive, and seven of D and six of ND following the 450-kPa dive. Although none suffered from DCS symptoms, a few individuals in both groups possessed VGE exceeding grade 3 K-M bubble scores in the 300- and 450-kPa dives. Severity of VGE stress increased with depth of dive in both groups, and despite the apparent higher tKISS scores in D (0.01 ± 0.05, 4.16 ± 11.28 and 8.51 ± 20.31 for the 180-, 300- and 450-kPa dives, respectively), these were not significantly different from ND (0.02 ± 0.05, 2.55 ± 7.14, 2.98 ± 4.11 for the 180-, 300- and 450-kPa dives, respectively).

There were no main effects of time or decompression following hyperbaric stress, interaction effects or between group differences for E, NE, GH or TRP (*Table 1*, facing page). There was a main effect of time for COR where the P20 and P60 values were both significantly reduced compared with the PRE sample (*Figure 1*, Page 224). The changes for ACTH are shown in Figure 2 *(Page 225)*, where the P20 sample was significantly reduced compared with PRE. There was also a main effect of decompression following hyperbaric exposure for ACTH where higher values were recorded for the low compared with the medium or high levels of hyperbaric exposure. Closer examination of the post-exposure samples revealed, however, that group D showed no change in ACTH during P20 or P60 following hyperbaric exposures. In contrast, the P20 sample was significantly higher for group ND after the 180-kPa exposure, and the P60 sample was increased following the 450-kPa exposure compared with D *(Figure 2)*.

TABLE 1

Neuroendocrine marker	Group	Low			Moderate			High		
		Pre	P20	P60	Pre	P20	P60	Pre	P20	P60
Epinephrine (pmol/L)	ND	294.5 (125.2)	394.0 (261.2)	732.4 (836.8)	350.9 (212.4)	267.3 (107.1)	460.0 (383.8)	257.5 (84.5)	394.6 (266.6)	316.1 (103.8)
	D	337.1 (324.7)	479.3 (416.3)	758.0 (967.3)	564.4 (494.4)	409.4 (268.6)	577.3 (451.7)	409.2 (421.5)	454.8 (279.8)	326.8 (176.5)
Norepinephrine (nmol/L)	ND	2.1 (1.5)	2.8 (1.2)	4.4 (6.3)	2.7 (1.6)	3.1 (1.7)	4.8 (6.1)	2.5 (1.5)	2.0 (1.1)	2.3 (1.4)
	D	2.3 (1.2)	3.1 (1.7)	2.9 (1.7)	2.8 (1.6)	2.4 (1.2)	2.7 (1.7)	2.5 (1.0)	3.0 (1.1)	2.3 (0.9)
Growth hormone (µg/L)	ND	0.3 (0.3)	1.9 (2.8)	1.5 (2.8)	0.2 (0.1)	1.2 (1.6)	0.9 (2.0)	0.2 (0.1)	1.2 (2.5)	0.3 (0.3)
	D	0.2 (0.2)	1.4 (2.2)	2.2 (5.9)	0.3 (0.5)	1.6 (3.1)	0.7 (1.1)	0.3 (0.4)	1.5 (2.2)	0.6 (0.6)
Tryptophan (µmol/L)	ND	82.6 (44.0)	91.8 (41.0)	68.8 (24.2)	94.5 (30.9)	66.9 (34.1)	80.5 (45.0)	89.4 (48.2)	72.0 (22.5)	62.9 (17.8)
	D	65.3 (26.2)	85.0 (25.2)	82.8 (38.9)	86.9 (35.9)	75.5 (33.1)	61.2 (18.4)	76.5 (41.0)	79.5 (40.2)	59.7 (38.5)

Table 1 – Neuroendocrine markers before (Pre) and 20 (P20) and 60 (P60) minutes following exposure to 180 (Low), 300 (Moderate) or 450 kPa (High) of pressure for 30 minutes for experienced divers (D) and non-divers (ND). Mean values (SD).

The changes in PRL were the most pronounced during the study and are presented in Figure 3 *(Page 226)*. There were significant main effects for the level of hyperbaric exposure and time as well as significant interaction effects between the level of hyperbaric exposure and time. Overall PRL levels were greater for group ND compared with D, and these differences were most evident during the P20 and P60 samples, with no group differences existing at baseline.

Mean reaction times during the PVT are shown in Figure 4 *(Page 227)*. Reaction time for ND prior to the 180-kPa exposure was significantly slower than the other Pre values. Exposure to the low level of hyperbaric stress had no effect on reaction times for either group, whereas both groups showed a slowing of reaction time at P20 following the 300-kPa exposure, but values had returned towards PRE by P60. In contrast, reaction times were significantly slowed for ND at both P20 and P60 following the 450-kPa exposure ,whereas the increases observed for D were not significant.

Individual changes in NE at P20 following the moderate level of hyperbaric stress were significantly correlated to the change in reaction time during the PVT ($r = 0.67$). Following 450-kPa exposure, both individual changes in PRL ($r = 0.52$) and COR ($r = 0.49$) were significantly correlated to changes in reaction time during the PVT at P20, and this significant correlation persisted for PRL at P60 ($r = 0.53$). There were no relationships observed between the changes in tKISS following the hyperbaric and decompression stress and the changes in neuroendocrine or psychomotor responses.

FIGURE 1

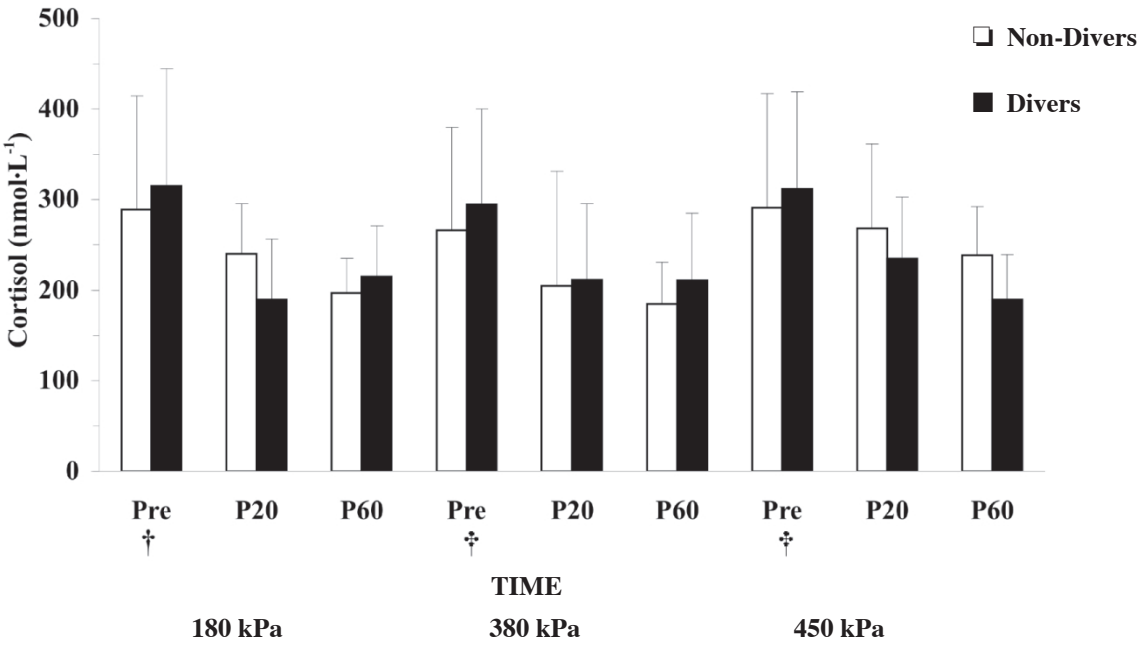


Figure 1 – Changes in cortisol before (Pre) and 20 (P20) and 60 minutes (P60) following exposure to 180, 300 and 450 kPa of hyperbaric and decompression stress for experienced divers and non-divers.

† *indicates that Pre values were significantly increased compared with P20 and P60 values.*

DISCUSSION

Although a previous study used a cross-sectional design to examine the serum antibody response to infectious waterborne pathogens in D and ND (32), the present study appears to be the first study to compare the impact of repeated hyperbaric and decompression stress on the adaptations within the neuroendocrine HPA axis and SAS in D and ND. Additionally, unique to our cross-sectional study was the attempt to relate changes in psychomotor performance to the changes in the neuroendocrine responses following exposure to the various levels of hyperbaric and decompression stress. The present investigation found little, if any, evidence to substantiate the involvement of the HPA axis and SAS, and few differences existed between ND and D in these neuroendocrine markers following exposure to the stress. The present study did reveal, however, that reaction time was slowed to a greater extent for the non-diving cohort following exposure to the highest level of hyperbaric and decompression stress, which was 450 kPa.

The current findings stand in contrast to others that have reported elevations in urinary excretion of E and NE throughout dry exposures to hyperbaric and decompression stress at 400-900 kPa and following a dive in sea water to 42 msw in experienced divers (7) or elevations in heart rate, as a surrogate measure of increased SAS activity, in experienced divers during a dive in sea water to 29 msw (6). However, in a group of naive diver trainees exposed to their first hyperbaric and decompression stress to 700 kPa, for a short duration of only 10 minutes, no changes in NE and decreases in E were observed (4). In the current study, there was no evidence to suggest that the involvement of the SAS was modified through recurrent periodic exposure to hyperbaric and decompression stress since responses for both D

FIGURE 2

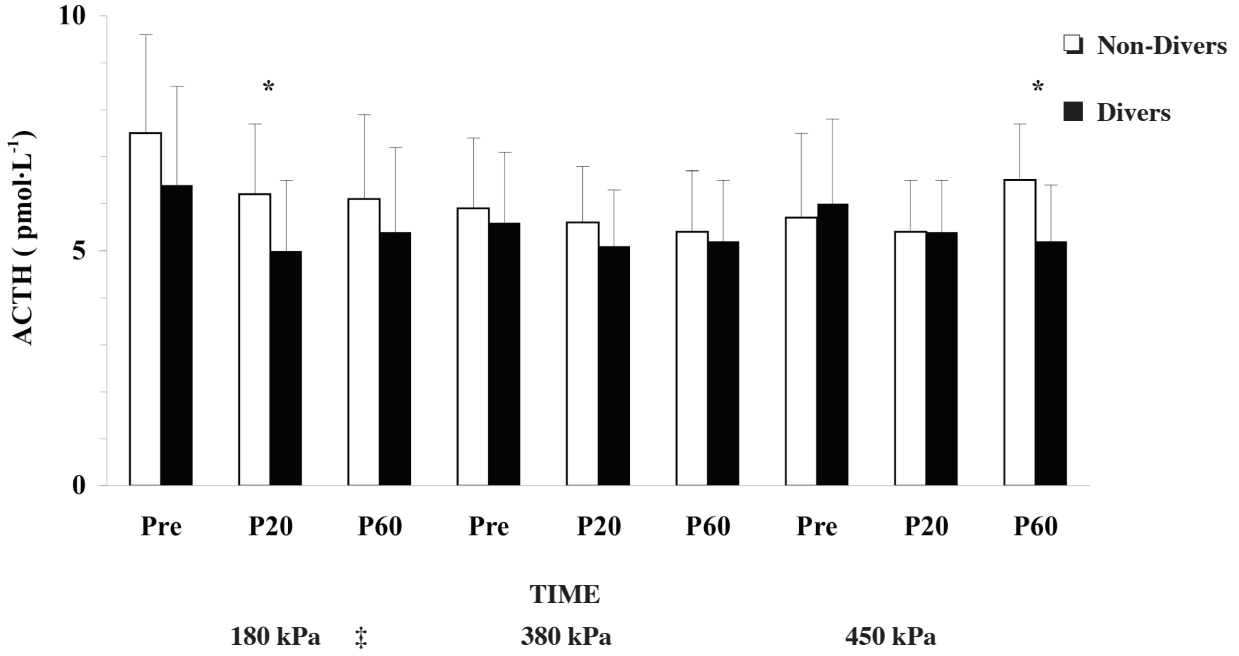


Figure 2 – Changes in adrenocorticotrophic hormone (ACTH) before (Pre) and 20 (P20) and 60 minutes (P60) following exposure to 180, 300 and 450 kPa of hyperbaric and decompression stress for experienced divers and non-divers.

‡ *indicates that the values during the 180-kPa exposure were significantly greater than during the 300- or 450-kPa exposures*.

* *indicates a significant difference between groups*.

and ND were similar. However, one important limitation to the interpretation of our findings was the inability to obtain blood samples immediately upon surfacing from the various levels of hyperbaric and decompression stress, given that the metabolic clearance and half-life of catecholamines is typically reported in minutes (33). However, Lund *et al*. (34) also observed little, if any, change in NE for professional divers during exposure for 60 minutes to 2.5 ATA and following 20 minutes after return to 1 ATA.

The current findings also have revealed little involvement of the HPA axis following exposures to the different hyperbaric and decompression levels of stress, as indicated by the lack of response in GH and the progressive decreases in COR, the latter being more consistent with the expected diurnal changes for the circulating concentrations of this hormone that show peak levels during the early morning hours (35). The minor exception was the elevation in ACTH for ND only, indicating perhaps some adaptation in the pituitary release of ACTH following repeated hyperbaric stress exposure. Again, our findings, contrast with the large increases in urinary excretion of COR following 35 minutes of hyperbaric stress (700 or 900 kPa) combined with up to 90 minutes of decompression stress (7). Our findings for COR are consistent, however, with the lack of change in COR that followed a brief 10-minute hyperbaric stress to 700 kPa and 15 minutes of decompression in diver trainees (4), the lack of consistent change in COR among five subjects involved in saturation exposures to 400 kPa or 1.1 MPa (24)

FIGURE 3

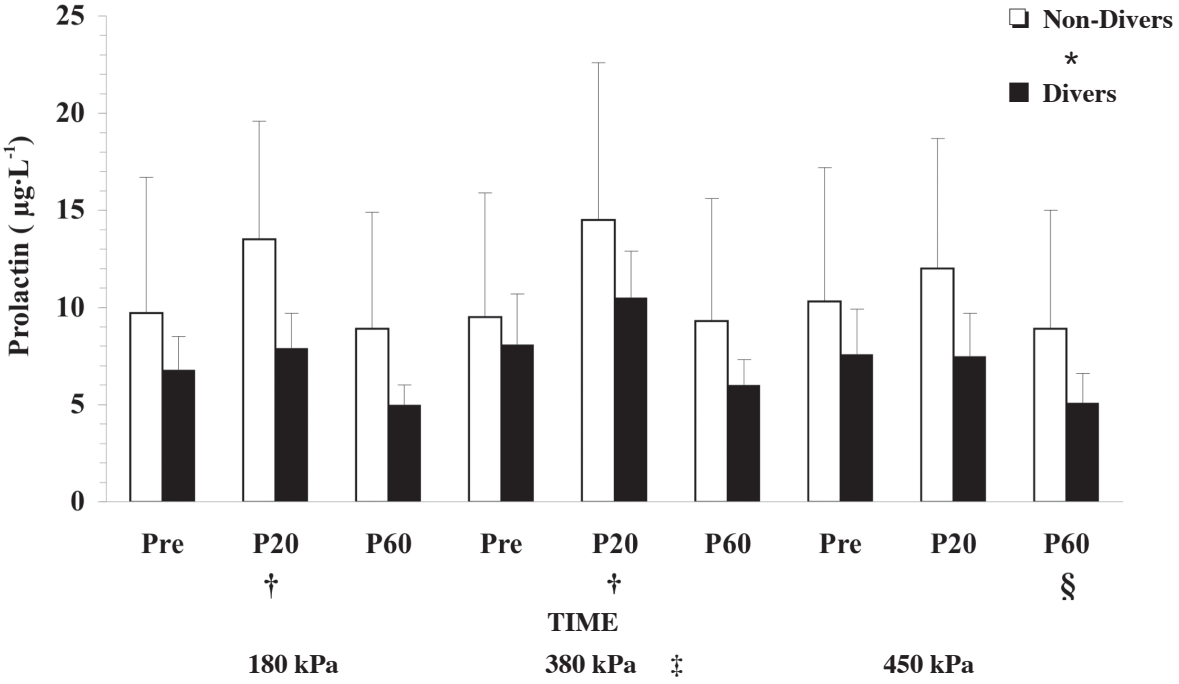


Figure 3 – Changes in prolactin before (Pre) and 20 (P20) and 60 minutes (P60) following exposure to 180, 300 and 450 kPa of hyperbaric and decompression stress for experienced divers and non-divers. ‡ indicates that the values during the 300-kPa exposure were significantly greater than during the 180- or 450-kPa exposures.
† *indicates a significant difference from Pre and P60.* § *indicates a significant difference from P20.*
* *indicates a significant difference between groups.*

and the decrease in COR observed during and following exposure to 2.5 ATA in professional divers (34).

In the present study it was hypothesized that the activation of the HPA axis and SAS would be greater for ND due to their inexperience with hyperbaric and decompression stress. In addition to the other stress hormones, we measured PRL and TRP since they have been suggested as peripheral markers of impending central fatigue (9-11, 19). Interestingly, PRL was higher for ND and increased more for this group following hyperbaric and decompression stress. In addition, we observed a moderate relationship between the increase in PRL and the change in psychomotor function. More recently, Reveli *et al.* (36) showed that well-trained professional divers did not develop anxiety and/or depression and maintained normal pulsatile COR and PRL secretion during a prolonged dive to an 8-m depth. Hyperbaric stress has been shown to impair memory, visual reaction time and sensory-motor performance (2, 5, 6) and Vaernes and Darragh (4) have shown that E, NE, COR and testosterone endocrine factors were related to various cognitive performance tests during exposure to 60 msw for a group of diver trainees. PRL was also increased following the dive to 60 msw, and the increases were moderately related to the reduction in recall capacity (4). Increased brain serotonin, which stimulates PRL release (9), has been linked to decreased CNS drive (20). It is tempting to suggest, therefore, that decreased CNS drive resulted in increased reaction time to the visual cue presented during the PVT. However, this relationship between PRL and reaction time during

FIGURE 4

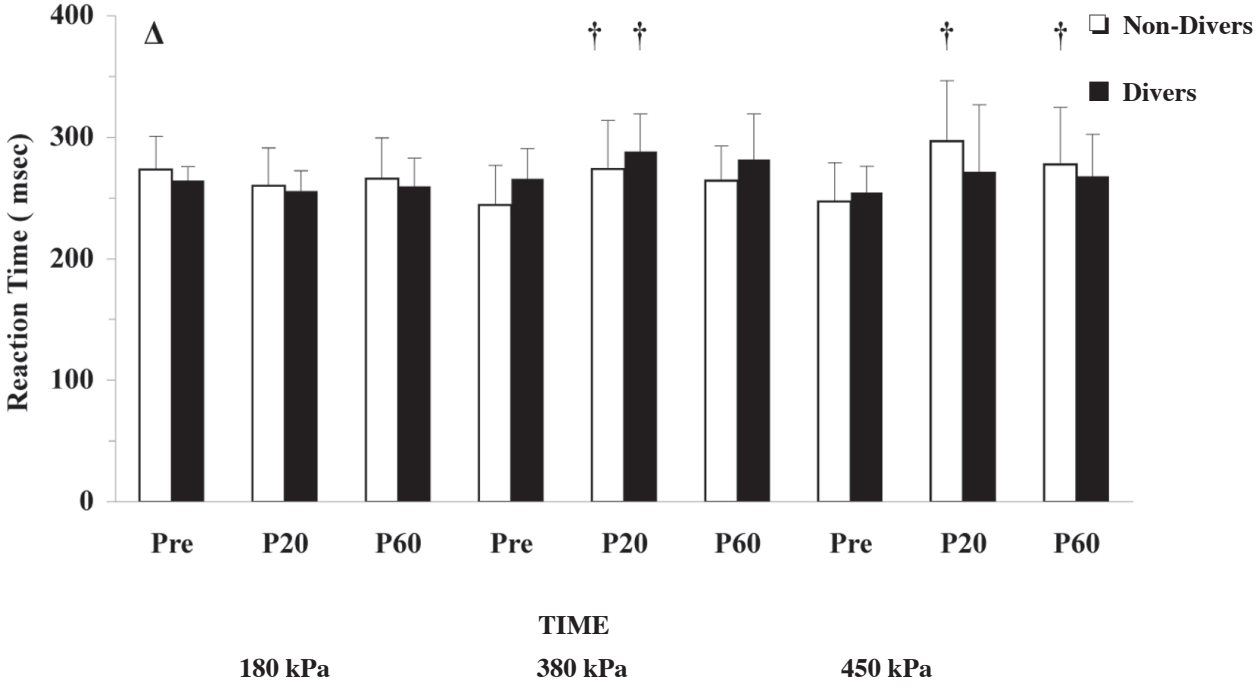


Figure 4 – Reaction time (msec) during the Psychomotor Vigilance Task before (Pre) and 20 (P20) and 60 minutes (P60) following exposure to 180, 300 and 450 kPa of hyperbaric and decompression stress for experienced divers and non-divers.

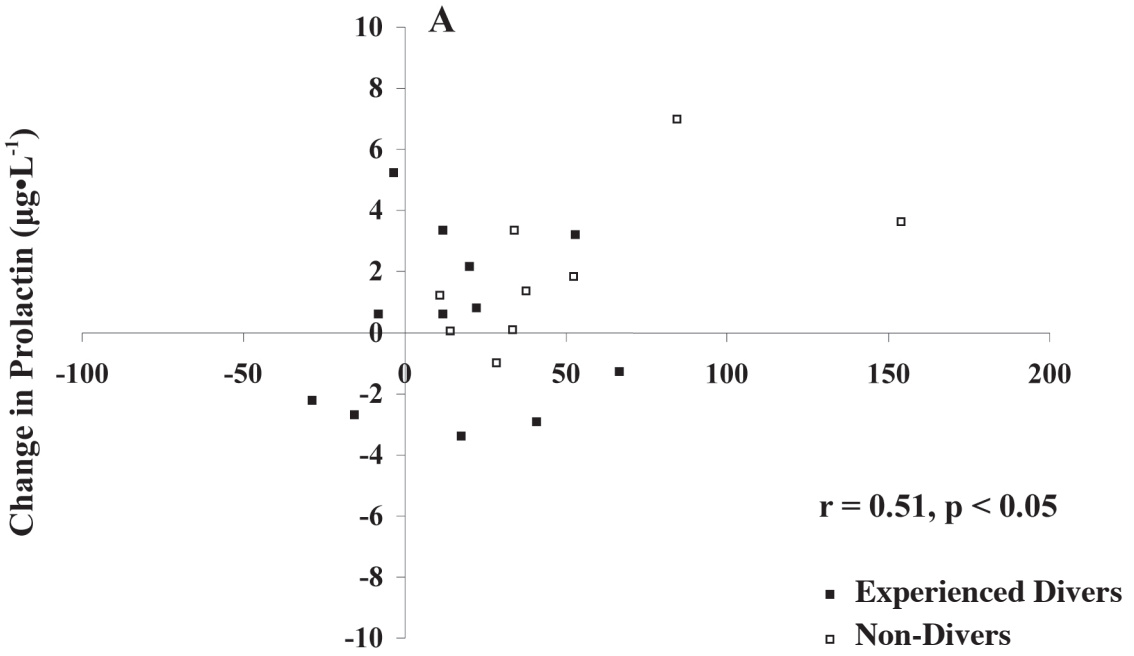
Δ *indicates a significant difference from the Pre values for the 300- and 450-kPa exposure for the non-divers.*
† *indicates a significant increase from the respective Pre reaction time.*

the PVT was skewed by the response of two NDs, who showed much greater changes in reaction time and PRL compared with the other subjects (*Figure 5A*, Page 228). Further, even though reaction time continued to be increased in these subjects 60 minutes following surfacing from the 450-kPa exposure, PRL values showed a return to pre-stress levels (*Figure 5B*, Page 228). In addition, a recent exercise and heat stress study reported that an increase in PRL, fourfold greater than in the present study (37), was also not accompanied by a change in reaction time (38). Thus, although PRL values in the peripheral circulation may serve as a surrogate index of brain serotonergic activity, the role of PRL in psychomotor function remains uncertain.

It is also important to remember that the concentration of any blood hormone may be influenced by pulsate secretion (39), and its value represents the balance between its release and sequestration in and clearance from the circulation (40, 41). Further, repeated exposure to a given stress and/or continued exposure to elevated circulating concentrations can lead to a change in receptor number and sensitivity as well as an altered effector response for a given change in concentration (42). Thus, although peripheral venous blood measurements of hormone concentrations provide an impression of the impact of hyperbaric and decompression stress for groups ND and D, changes in values cannot be empirically assumed to result from a change in turnover or clearance alone.

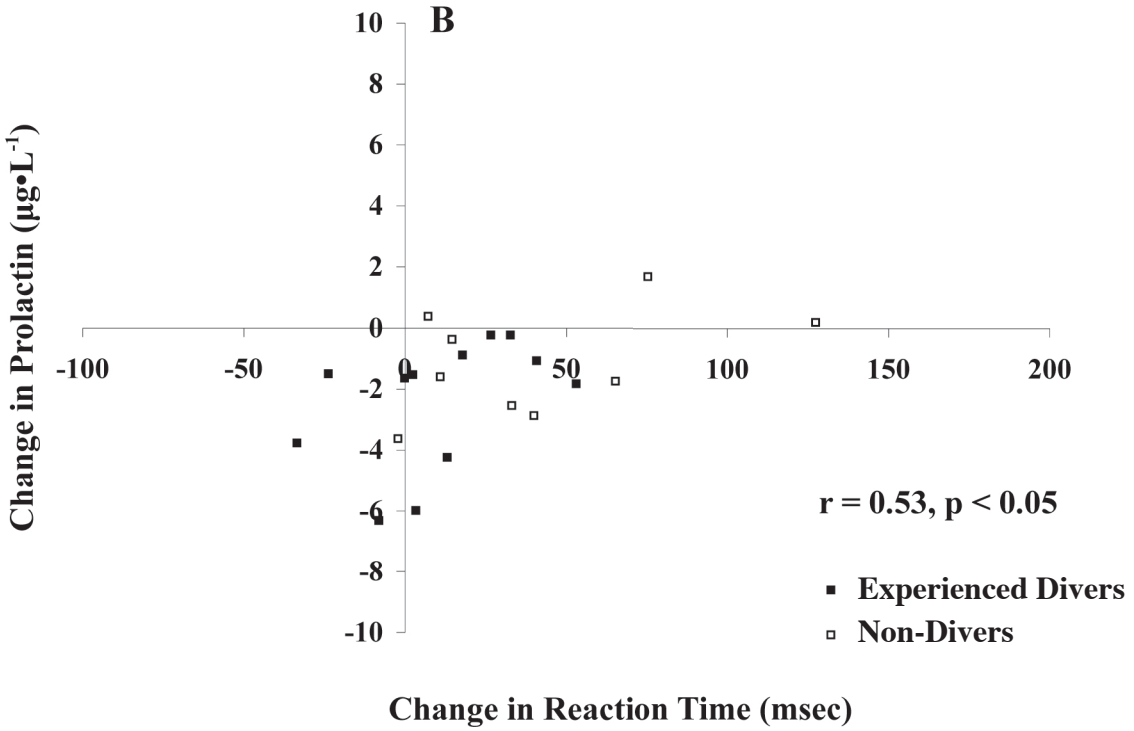
Our choice of sampling intervals at 20 and 60 minutes following resurfacing was selected to coincide with the continued evolution of Doppler-

FIGURE 5A



Figures 5a and 5b – Individual changes in prolactin plotted against changes in reaction time measured with the psychomotor vigilance task for experienced divers and non-divers. Values represent the difference between values obtained either 20 minutes (A, *above*) or 60 minutes (B, *below*) following 30 minutes of hyperbaric exposure to 450 kPa with the accompanying decompression stress during the return to surface and baseline values obtained before exposure.

FIGURE 5B



measured bubbles following decompression. Given the low Doppler-detected bubble scores in the present study, it is possible that greater differences in hormone changes may have existed between groups immediately after surfacing. Yet, intracellular inflammatory cytokines and altered gene expression were apparent 60 minutes following the return to the surface, and the magnitude of these changes were related to the severity of the hyperbaric and decompression stress (43). Given the established relationships between changes in NE and GH, for example, and immunomodualtion and inflammatory cell signaling (44-46), we expected to see differences in these hormones between our groups, given the marked differences observed in the immune-inflammatory activation.

In summary, 20 and 60 minutes following surfacing from 180, 300 or 450 kPa, there was little, if any, evidence to substantiate the involvement of the HPA axis and SAS during the varied levels of hyperbaric and decompression stress. Further, few differences existed between ND and D in these neuroendocrine markers following exposure to the stress. However, there was a greater increase in reaction time for ND following the exposure to the 450-kPa hyperbaric and decompression stress that persisted for 60 minutes following return to the surface. Changes in PRL after surfacing were moderately related to the increase in reaction time, but changes in reaction time persisted for longer durations after surfacing than did changes in circulating PRL levels.

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