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MEASUREMENT OF HEART RATE VARIABILITY AND SALIVARY CORTISOL LEVELS IN BEGINNER SCUBA DIVERS

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Abstract

Scuba diving, an expensive form of extreme sport, remains popular despite the world wide economic recess. Part of its popularity is ascribed to the fact that it allows for sensation seekers to experience novel experiences. Research has indicated that novel experiences induce stress responses in human beings. Amongst scuba divers, this stress response was often measured with psychometric instruments after dives had occurred. The problem, however, is that to understand the stress response one must not only study the psychological dimension, but also needs to investigate its physiological impact on the body. In the scuba diving environment though, it not preferable to measure it after a scuba dive had occurred. Researchers have discovered that anticipating being confronted with a novel experience could elicit a physiological stress response. Because of this, it is theorized that scuba divers would experience a stress response by merely anticipating being underwater. The aim of the present study was to determine if a physiological stress response occurred in a group of beginner divers. Since these divers are also confronted with a series of novel experiences during their training, another aim of the study was to investigate how the stress response manifested physiologically as the course progressed. Sixty divers participated in the study. Heart rate measurements and salivary specimen were taken on three occasions: at rest (baseline), before entering the pool to practice scuba skills and before participating in the first open water dive. Cortisol was extracted from the salivary specimen. The results indicated that significant differences occurred in cortisol levels between the baseline and before entering the pool measurements. Significant differences were also observed between the baseline and before the open water dive measurements. Heart rate yielded significant differences between the baseline and before the pool measurements, as well as between the pool and before the open water dive measures. The findings indicated that beginner divers experienced a physiological stress response as a result of anticipating taking part in a novel experience. It further suggested that, as their training progressed, the stress response did not disappear but was controlled or inhibited after the first encounter with the underwater environment. The reason for this is that different systems in the sympathetic nervous system are responsible for the activation of cortisol and heart rate.

Keywords: Extreme sport, recreational Scuba diving, beginner Scuba divers, heart rate, cortisol.

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Introduction

Recreational scuba diving, an expensive extreme sport, remains as popular as ever despite the world wide economic recess (PADI, 2011). In New Zealand for example, scuba diving was rated as popular as squash by 121 625 participants. The only other water-based sport indicated to be more popular than scuba diving was swimming (Sport & Recreation New Zealand, 2009). A report by Pendleton and Rooke (n.d) estimated that by 2010, scuba diving would have contributed $81 million to the economy of California.

Because of the physical and psychological risks involved with scuba diving (Jack & Ronan, 1998; Slanger & Rudestam, 1997; Zuckerman, 1983; 1994; 2000), scuba divers are often described as individuals seeking novel experiences (Murray, 2003; Zuckerman, 2000, 1994). Exposure to novel experiences, however, could evoke a stress response in human beings (Lyon, 2000; Musikanth, 1996; Weinberg & Gould, 2007). Anegg et al. (2002) concluded that, within the scuba diving environment, this stress response often results in inappropriate behaviour displayed in the forms of anxiety and panic. This notion was confirmed by Morgan's (1995) research where 54% of the divers participating in the study confessed to experiencing at least one episode of panic whilst diving. In an attempt to explain why panic occurs amongst novice as well as experienced divers, researchers such as Koltyn, Shake, and Morgan (1993), Morgan (1987) as well as Morgan, Lanphier, Raglin, and O'Connor (1989) turned to the psychological measurement of anxiety. Based on the work of Spielberger, Gorsuch, and Lushene (1970), these researchers postulated that divers measuring high on trait anxiety will be more prone to display high levels of state anxiety, which could result in a state of panic when exposed to a novel experience (Koltyn et al., 1993; Morgan, 1987; Morgan et al., 1989). Zuckerman (1990), however, contended that sensation seekers (such as scuba divers) experience a psychophysiological response when exposed to novel experiences. One could thus not only focus on the psychological response to the novel experience, but should also take cognizance of the physiological reaction to such an experience. Reviewing the literature though, it becomes evident that research on this issue is scarce. One might argue that the reason for this is that it is difficult to take any form of physiological measurement whilst divers are underwater. This will also explain why psychometric instruments have been so popular; the latter has the proven ability to measure psychological traits which in turn could be used to predict behaviour (Murphy & Davidshofer, 2005).

To equate being underwater to a novel experience might however be an incorrect assumption. The Response Based Approach developed by Hans Selye (1976) indicated that it is not the environment that induces the stress response, but the individual's **perception** of a particular stimuli from within the environment. The Transactional Approach developed by Richard Lazarus agreed with Selye's view and postulated that one of the factors necessary for the stress response to occur is a cognitive (subjective) appraisal of an event as possibly stressful (Lyon, 2000). Research conducted by Bonifazi, Sardella, and Lupo (2000) provided scientific support for these theoretical approaches. These researchers monitored plasma cortisol concentrations in a group of elite swimmers. They discovered that plasma cortisol concentrations were at its highest levels just before the competition season started. In another study using cortisol analysis, Takai and his colleagues showed participants a video (Takai et al., 2004). Participants reported that the video evoked a stress response in them. When their cortisol levels were measured, participants demonstrated an increase in their cortisol levels (Takai et al.. 2004). All these findings concurred with the results of a study conducted by Passelergue and Lac (1999). When researching the stress response in a group of wrestlers, the researchers found that wrestlers displayed elevated levels of cortisol even before competitions started. According to Passelergue and Lac, these wrestlers experienced an anticipatory response which caused the increased cortisol levels.

It however seems that cortisol is not the only physiological indicator of the stress response that increases significantly when individuals are anticipating a potential stressful situation. In a study conducted by Maughan and Gleeson (2008), the researchers discovered that heart rate was affected when armchair football supporters watched a televised football match. The researchers concluded that physiological responses were "... strongly influenced by the perception of [the] event" (Maughan & Gleeson, 2008, p. 22). In yet another study conducted by Fenz and Jones (1972) on novice parachutists, the researchers discovered that heart rate increased significantly even before the parachutists performed their jump. Bernardi et al. (2000) concluded that simple mental activities, such as talking and reading, could have a marked influence on heart rate variability. It is therefore concluded that mental anticipation of engaging in a novel experience would result in changes in heart rate variability.

Based on the discussions presented above, it is now assumed that being underwater is not the only novel experience that causes a stress response in scuba divers. It is postulated that anticipating being underwater could result in a physiological stress response. The aim of this study was therefore to determine if a physiological stress response occurred in a group of beginner divers. Since beginner divers are confronted with a series of novel experiences during their training, another aim of the study was to determine that, if a stress response occurred, how this response manifested physiologically during the course of their training.

The stress response was measured by assessing cortisol levels and heart rate variability. These appear to be the most common forms of measurement when research is conducted on the physiology of the stress response (Ditzena et al., 2007; Kudielka, Wüst, Kirschbaum & Hellhammer, 2007; Maughan & Gleeson, 2008; Rimmele et al., 2007; Weber et al., 2008).

One of the important systems playing a role during the stress response is the corticolimbic system (Coetzee, 2005). The corticolimbic system is a circuit of interconnected brain structures. The most notable of these is the hypothalamus (Kandel, Schwartz, & Jessell, 1995). When a stress response occurs, the hypothalamus releases hormones that activate the endocrine system (Collins, Sorocco, Haala, Miller, & Lovallo, 2003; Kandel et al. 1995; Moreira et al., 2009; White & Mattson Porth, 2000; Weiten, 2004). This results in the occurrence of the adrenocorticol response (Collins et al.). The adrenocorticol response is caused when the paraventricular nucleus of the hypothalamus releases a corticotropin-releasing factor (CRF) that travels to the anterior pituitary gland (Coetzee; Collins et al.). The anterior pituitary gland is then induced to secrete a hormone, adrenocorticotropic (ACTH), which in turn stimulates the adrenal cortex to secrete another hormone, cortisol (Green & Shellenberger, 1991; Kalat, 2007; Stöppler, 2003; White & Mattson Porth). Cortisol is perceived as a marker of activity in the hypothalamic-pituitary-adrenal-corticol system (Aubets & Segura, 1995). Collins et al. noted that cortisol "… is responsible for increasing sympathetic nervous system function, releasing stored glucose and fats for energy …" (pp. 171-172).

As a result of the increased activity in the sympathetic nervous system, another response occurs, namely the adrenomedullary response. This response involves the release of epinephrine and norepinephrine (Collins et al., 2003; Green & Shellenberger, 1991; Groves & Rebec, 1992). These hormones stimulate the heart's muscles and cause an increase in heart rate, blood pressure and oxygen levels (Coetzee, 2005; Collins et al.; Groves & Rebec). Heart rate variability is thus an indicator of cardiac output and the total amount of blood flowing through the circulation system of the human body (Silverthorn, 1998). A stressed individual will therefore display an increase in the amount of blood the heart's ventricle pumps per minute (White & Mattson Porth, 2000). This will enable the person to display the fight-or-flight response (Weiten, 2004). In the face of such evidence, White and Mattson Porth concluded that heart rate variability could be used as a state-dependant measure of stress.

Materials and Methods

Beginner recreational scuba divers from the same geographical area participated in the study since the amount of years participating in the sport as well as environmental inconsistencies (such as diving for the first time in the sea) could act as extraneous variables when measuring an anticipatory response (Roberts & Wood, 2006). Ten scuba diving schools within Gauteng were randomly selected from the South African Divers Alert Network website (www.dan-sa.org) to be included in the study but only six agreed to participate. Newly enrolled beginner divers were identified and asked to volunteer to participate in the study. Sixty (60) divers (30 males; 30 females) volunteered to serve as participants. Participating divers were aged from 16 to 35 years (M = 27.6, SD = 4.74). Each participant signed a consent form to confirm their voluntary participation in the study and to indicate that the results may be used for research purposes.

Measurements used in the study

Heart rate variability. A battery operated Microlife monitor with cuff was utilised according to the instructions provided by the manufacturer to measure heart rate variability. The instrument provided an electronic reading of the heart rate of the participants.

Salivary cortisol. Obtaining samples of salivary cortisol is deemed the least intrusive form of measuring cortisol (Gaab et al., 2003; Takai et al., 2004; Takashi et al., 2004). It also has been proven to be a valid and reliable measure of cortisol (Rimmele et al., 2007). Salivary samples were obtained by requesting the participants to spit into a sterile specimen bottle. Participants were requested not to eat or drink anything before presenting their samples. The sample specimen was stored at -27ºC. After all the necessary samples were obtained, it was analysed using the Active Cortisol EIA (For Saliva) DSL-10-67100 assay kit obtained from Diagnostic Systems Laboratories. The biochemical analysis was conducted by a qualified biochemist according to the manufacturer’s specifications.

Data Collection

Each scuba diving school was visited, according to prior arrangement with the scuba instructor, by the researcher on the day of the commencement of the entry-level divers’ scuba diving training. Participants at this stage did not receive any form of lectures or instructions from the scuba instructor. Their heart rate was measured and salivary specimen was obtained. These were labelled the baseline measures for the participants.

The next measure was taken after the participants received their theoretical training but before they entered the swimming pool (which ranged in depth from three to five metres) to apply their theoretical knowledge to an underwater setting. These were labelled as “Before the pool” measures.

Final measures were taken right before participants donned their scuba equipment to participate in their first open water dive. All open water dives occurred in confined open water spaces such as dams or quarries filled with water. These measurements were labelled “Before the open water dive”.

Data Analysis

When conducting the data analysis, it seemed that the measures of heart rate variability were hugely affected by attrition. During the course of the study, several participants had to withdraw as a result of physical impairments induced by the underwater environment on their bodies. In addition to this, when the salivary specimen was analysed, it was discovered that several samples did not meet the criteria set by the manufacturer’s standard protocols and had to be discarded. The latter especially had a severe impact on the sample size of the salivary specimen. The remaining specimen, however, yielded a sample of more than 30, which is adequate for further data analysis (Levin & Fox, 2011; Pallant, 2010).

Results and Discussions

In order to measure central tendency, mean scores were computed for each of the measures of heart rate and cortisol. Variability was measured by calculating the standard deviations for these scores. The results obtained are indicated in Tables 1 and 2.

Table 1: Means and standard deviations for each of the measures of heart rate

Measure	*N*	*M*	*Sd*
Baseline	51	74.82	15.99
Before the pool	51	85.41	15.63
Before open water dive	51	78.55	12.93

Table 2: Means and standard deviations for each of the measures of cortisol (µg/dl)

Measure	*N*	*M*	*Sd*
Baseline	34	0.33	0.33
Before the pool	34	0.79	0.82
Before open water dive	34	0.67	0.58

As can be seen in Table 1, the mean heart rate was the highest before the participants entered the pool. Standard deviations were high across the three measures, indicating a lot of variability in the measured heart rates. Table 2 indicates that the highest mean cortisol level also occurred before the pool was entered. When the standard deviations for the different measures of cortisol levels had been compared, huge differences were observed across the three measures. Initially, little variance occurred. The highest amount of variability was displayed, as was the case with the means, before the participants entered the pool. The standard deviation related to the measure taken before the open water dive was considerably lower than the one associated with the pool session. It, however, was still higher than the standard deviation reported for the baseline.

In order to determine if significant differences had occurred with regards to heart rate, a one-way repeated measures ANOVA was conducted between the measures taken at the baseline, before the pool was entered and before the first open water dive was undertaken. The results are presented in Table 3.

Table 3: A summary of the one-way repeated measures ANOVA for heart rate

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.293	10.131[a]	2.000	49.000	.000	.293
Wilks' lambda	.707	10.131[a]	2.000	49.000	.000	.293
Hotelling's trace	.414	10.131[a]	2.000	49.000	.000	.293
Roy's largest root	.414	10.131[a]	2.000	49.000	.000	.293

Table 3 indicates that there was significant differences with regards to heart rate across the three measurements, Wilks' Lambda = 0.71, $F(2, 49) = 10.13$, $p < 0.05$, multivariate partial eta squared = 0.29.

According to the Pairwise Comparisons Table generated along with the output from the one-way repeated measures ANOVA, significant differences occurred between the baseline measurement and the measurement taken before participants entered the pool ($p < 0.05$). Significant differences were also observed between the measure taken before the pool was entered and the measure taken before the open water dive ($p < 0.05$) (Table 4).

Table 4: Pairwise comparisons with regards to the three measures of heart rate

(I) Measure	(J) Measure	Mean Difference (I-J)	Std. Error	Sig[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-10.588*	2.403	.000	-16.542	-4.634
	3	-3.725	2.296	.333	-9.414	1.963
2	1	10.588*	2.403	.000	4.634	16.542
	3	6.863*	2.164	.008	1.503	12.222
3	1	3.725	2.296	.333	-1.963	9.414
	2	-6.863*	2.164	.008	-12.222	-1.503

A one-way repeated measures ANOVA was also conducted between the three measures of salivary cortisol to determine if significant differences occurred. The results are presented in Table 5.

Table 5: A summary of the one-way repeated measures ANOVA for cortisol (µg/dl)

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.416	11.405[a]	2.000	32.000	.000	.416
Wilks' lambda	.584	11.405[a]	2.000	32.000	.000	.416
Hotelling's trace	.713	11.405[a]	2.000	32.000	.000	.416
Roy's largest root	.713	11.405[a]	2.000	32.000	.000	.416

Table 5 shows that significant differences occurred with regards to salivary cortisol levels across the three measurements, Wilks' Lambda = 0.58, $F(2, 32) = 11.41$, $p < 0.05$, multivariate partial eta squared = 0.42. Once again, the Pairwise Comparisons Table was consulted to determine where the significant differences had occurred.

As can be seen in Table 6, significant differences occurred between the baseline measurement and the measurement taken before participants entered the pool ($p < 0.05$). Significant differences were also observed between the baseline measurement and the measure taken before the open water dive ($p < 0.05$). Unlike it was the case with heart rate, no significant differences were observed between the measure taken before the pool was entered and the measure taken before the first open water dive.

Table 6: Pairwise comparisons with regards to the three measures of cortisol (µg/dl)

(I) Measure	(J) Measure	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-.463*	.144	.009	-.826	-.101
	3	-.344*	.100	.005	-.597	-.091
2	1	.463*	.144	.009	.101	.826
	3	.120	.180	1.000	-.335	.574
3	1	.344*	.100	.005	.091	.597
	2	-.120	.180	1.000	-.574	.335

Since both heart rate and salivary cortisol levels increased significantly (see Tables 4 and 6) between the baseline measure and the measure taken before the pool was entered, it is concluded that the participants in this study experienced a physiological stress response as a result of anticipating a novel experience (being underwater for the first time). These findings not only concur with the results obtained by Bonifazi et al. (2000), Passelergue and Luc (1999) and Takai et al. (2004) when studying changes in cortisol levels, it also confirmed the results related to heart rate variability obtained by Fenz and Jones (1972) as well as Maughan and Gleeson (2008). It is of great interest to note that the results with regards to salivary cortisol levels and heart rate variability only displayed similar patterns between the baseline measurement and the measurement taken before the pool was entered. Although these results are interesting, it is not surprising. According to Gray's two-factor learning theory, any form of arousal is impacted upon by two systems, namely the behavioural activation system (BAS) and the behavioural inhibition system (BIS) (Fowles, 1980; Heponiemi, Keltikangas-Järvinen, Puttonen, & Ravaja, 2003). The BIS produces anxiety when confronted with potential stressful or novel experiences (Fowles; Heponiemi et al., 2003). It has been shown that anxiety and stress are interrelated concepts within the scuba diving context (Anegg et al., 2002). In order to cope with these emotions, cortisol is released (Coetzee, 2005; Green & Shellenberger, 1991; Kalat, 2007; Stöppler, 2003; White & Mattson Porth, 2000). As was discussed earlier, cortisol increases sympathetic nervous functioning which in turn affects heart rate. The latter increases energy levels to target organs that enable the body to effectively deal with the stressor. Cortisol could thus be associated with BIS activity because, by activating specific systems in the sympathetic nervous system, it prevents (inhibits) the body from activating the wrong physiological systems when dealing with a novel or stressful experience (Heponiemi, Keltikangas-Järvinen, Kettunen, Puttonen, & Ravaja, 2004). Heart rate, on the other hand, is associated with activity of the BAS which initiates behaviour (Fowles, 1980; Heponiemi et al., 2004). According to Fowles and Heponiemi et al. (2004), two types of behaviour result from BAS activity, namely approach or avoidance behaviour. In a context where stress responses are investigated, these behaviours would constitute the fight-or-flight response. Heart rate therefore displayed significant differences, not only between the baseline measurement and the measurement taken before the pool session, but also between the pool session and the first open water dive because the BAS was activated. This implies that physiologically, the divers' bodies prepared them to approach (fight) or avoid (flight) the newest novel experience introduced by the next level of their training.

In light of the above discussion it is postulated that, since cortisol and heart rate form part of different behavioural systems, **prolonged** exposure to the novel experience (being underwater) will yield different statistical results for both constructs. According to Fenz and Jones (1972), such differences occur as a result of a hierarchy of reactions the body display when experiencing the stress response. Because cortisol secretion forms part of the BIS and is responsible for the activation of the sympathetic nervous system, it is assumed that this response had declined as the participants' training progressed. It is however important to note that it did not cease to exist since there was still a significant difference in the results of the baseline salivary cortisol measurement and the measurement taken before the first open water dive. The stress response therefore did not disappear but was controlled or inhibited to some extent after the first encounter with the underwater environment (Fenz & Jones). The significant increase in heart rate which occurred between the pool measurement and the measurement taken before the first open water dive, confirm this and shows that the participants still experienced a stress response when they moved from one level of their training to the next. As was indicated earlier, this stress response also, on a subconscious level, placed them before a decision: approach or avoid the next level of training.

Reviewing the discussions presented thus far it is concluded that anticipating being underwater resulted in a stress response in a group of beginner divers. Initially this stress response indicated similar patterns for heart rate variability and changes in cortisol levels. However, as the participants' training progressed, the stress response manifested differently for cortisol levels and heart rate variability. The latter could be ascribed though to the fact that cortisol and heart rate are by-products of two different behavioural systems associated with the sympathetic system (Beauchaine, 2001).

Because of the small sample size used in the present study, it is suggested that the present findings must be interpreted with some caution. It is further recommended that future studies should attempt to use bigger samples. Due to the complexity of the physiology of the stress response, it is also recommended that more research is necessary to determine the extent of the stress response as a result of an anticipatory reaction to a novel experience. More research is also needed to investigate the roles of heart rate variability and cortisol during the experience of a stress response.

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References

Anegg, U., Dietmaier, G., Maier, A., Tomaselli, F., Gabor, S., Kallus, K.W. & Smolle-Jüttner, F.M. (2002). Stress-induced hormonal and mood responses in scuba divers: A field study. *Life Sciences, 70*(23), 2721-2734.

Aubets, J., & Segura, J. (1995). Salivary cortisol as a marker of competition related stress. *Science & Sports 10*, 149-154.

Bernardi, L., Wdowczyk-Szulc, J., Valenti, C., Castoldi, S., Passino, C., Spadacini, G. & Sleight, P. (2000). Effects of controlled breathing, mental activity and mental stress with or without verbalization on heart rate variability. *Journal of American College of Cardiology, 35*(6), 1462-1469.

Beauchaine, T.P. (2001). Vagal tone, development, and Gray's motivational theory: Toward an integrated model of autonomic nervous system functioning in psychopathology. *Development & Psychopathology, 13*, 183-214.

Bonifazi, M., Sardella, F. & Lupo, C. (2000). Preparatory versus main competitions: differences in performances, lactate responses and pre-competition plasma cortisol concentrations in elite male swimmers. *European Journal for Applied Physiology 82*, 368-373.

Coetzee, N. (2005). *Behavioural correlates, stress, anxiety and panic in recreational scuba divers: A psychophysiological perspective*. Unpublished doctoral dissertation, University of Limpopo, Medunsa Campus, South Africa.

Collins, F.L. (Jr.), Sorocco, K.H., Haala, K.R., Miller, B.I. & Lovallo, W.R. (2003). Stress and Health. In L.M. Cohen, D.E. McChargue & F.L. Collins, Jr. (Eds.), *The health psychology handbook: Practical issues for the behavioral medicine specialist* (pp. 169-186). Thousand Oaks: Sage Publications.

Ditzena, B., Inga, B., Naumannc, D., Bodenmannd, G., Von Dawanse, B., Turnerf, R.A., Ehlerta, U., & Heinrichse, M. (2007). Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in women. *Psychoneuroendocrinology, 32*(5), 565-574.

Fenz, W.D. & Jones, B. (1972). Individual differences in Physiologic Arousal and Performance in Sport Parachutists. *Psychosomatic Medicine*, *34*(1), 1-8.

Fowles, D.C. (1980). The three arousal model: Implications of Gray's Two-Factor Learning Theory for heart rate, electrodermal activity and psychopathy. *Psychophysiology, 17*(2), 87-104.

Gaab, J., Blättler, N., Menzi, T., Pabst, B., Stoyer, S. & Ehlert, U. (2003). Randomized controlled evaluation of the effects of cognitive-behavioral stress management on cortisol responses to acute stress in healthy subjects. *Psychoneuroendocrinology, 28*, 767-779.

Green, J. & Shellenberger, R. (1991). *The Dynamics of Health and Wellness: A Biopsychosocial Approach*. Fort Worth, Chicago: Holt, Rinehart and Winston, Inc.

Groves, P.M. & Rebec, G.V. (1992). *Introduction to Biological Psychology* (4^{th} ed.). United States of America: Wm. C. Brown Publishers.

Heponiemi, T., Keltikangas-Järvinen, L., Kettunen, J., Puttonen, S. & Ravaja, N. (2004). BIS-BAS sensitivity and cardiac autonomic stress profiles. *Psychophysiology, 41*, 37-45.

Heponiemi, T., Keltikangas-Järvinen, L., Puttonen, S. & Ravaja, N. (2003). BIS/BAS sensitivity and self-rated affects during experimentally induced stress. *Personality and Individual Differences, 34*, 943-957.

Jack, S.J. & Ronan, K.R. (1998). Sensation seeking among high- and low-risk sports participants. *Personality and Individual Differences*, *25*, 1063-1083.

Kalat, J.W. (2007). *Biological Psychology* (9^{th} ed.). Australia: Thomson Wadsworth.

Kandel, E.R., Schwartz, J.H., & Jessell, T.M. (1995). *Essentials on Neural Science and Behavior*. (International ed.). United States of America: Prentice Hall International, Inc.

Koltyn, K.F., Shake, C.L. & Morgan, W.P. (1993). Interaction of exercise, water temperature and protective apparel on body awareness and anxiety. *International Journal of Sport Psychology, 24*, 297-305.

Kudielka, B.M., Wüst, S., Kirschbaum, C. & Hellhammer, D.H. (2007). Trier Social Stress Test. *Encyclopedia of Stress*, 776-781.

Levin, J., & Fox, J.A. (2011). *Elementary statistics in social research: The essentials*. (3rd ed.). Boston: Allyn & Bacon.

Lyon, B.L. (2000). Stress, coping and health: A conceptual overview. In V.H. Rice (Ed.), *Handbook of stress, coping and health: Implications for nursing research, theory, and practice* (pp. 3-23). Thousand Oaks: Sage Publications, Inc.

Maughan, R.J., & Gleeson, M. (2008). Heart rate and salivary cortisol responses in armchair football supporters. *Medicina Sportiva 12*(1), 20-24.

Moreira, A., Arsati, F., De Oliveira Lima Arsati, Y.B., Da Silva, D.A., & De Araújo, V.C. (2009). Salivary cortisol in top-level professional soccer players. *European Journal for Applied Physiology, 106*, 25-30.

Morgan, W.P. (1987). *Psychological characteristics of the female diver: Women in diving*. Proceedings of the thirty-fifth Undersea and Hyperbaric Medical Society Workshop held in Bethesda, Maryland. UHMS publication number 71 (WS-WD) 3/15/87.

Morgan, W. P. (1995). Anxiety and Panic in Recreational Scuba Divers. *Sports Medicine, 20*(6), 398-421.

Morgan, W.P., Lanphier, E.H., Raglin, J.S., & O'Connor, P.J. (1989). *Psychological considerations in the use of breathing apparatus: Physiological and human engineering aspects of underwater breathing apparatus*. Proceedings of the 40th Undersea and Hyperbaric Medical Society Workshop held at Center for Research in Special Environments, School of Medicine and Biomedical Sciences, University of Buffalo, State University of New York. UHMS publication number 76(UNDBR) 10/1/89.

Murray, D.M. (2003). *Living on the edge: Sensation seeking and extreme sports participation*. Unpublished dissertation, University of Connecticut, United States of America.

Murpy, K.R. & Davidshofer, C.O. (2005). *Psychological Testing: Principles and Applications*. (6th ed.). United States of America: Prentice Hall International, Inc.

Musikanth, S. (1996). *Stress Matters*. Rivonia: William Waterman Publications.

Padi. (2011). *World-wide corporate statistics 2010*. Retrieved from http://www.padi.com

Pallant, J. (2007). *SPSS Survival Manual* (3rd ed.). Berkshire, England: McGraw Hill Open University Press.

Passelergue, P. & Lac, G. (1999). Saliva cortisol, testosterone and T/C ration variations during a wrestling competition and during the post-competitive recovery period. *International Journal of Sports Medicine 20*, 109-113.

Pendleton, L.H. & Rooke, J. (n.d.) Understanding the potential economic value of SCUBA diving and snorkelling. Retrieved from http://www.dfg.ca.gov/mlpa/pdfs/draft_dive.pdf

Rimmele, U., Zellweger, B.C., Marti, B., Seiler, R., Mohiyeddini, C. & Heinrichs, M. (2007). Trained men show lower cortisol, heart rate and psychological responses to psychosocial stress compared with untrained men. *Psychoneuroendocrinology, 32*, 627-635.

Roberts, B.W. & Wood, D. (2006). Personality development in the context of the Neo-Socioanalytic Model of personality. In D.K. Mroczek & T.D. Little (Eds.). *Handbook of Personality Development,* pp. 11-39. New Jersey: Lawrence Erlbaum Publishers.

Selye, H. (1976). *The stress of Life*. (Revised edition). New York: McGraw-Hill Book Company.

Silverthorn, D.U. (1998). *Human physiology: An Integrated Approach*. Upper Saddle River, New Jersey: Prentice Hall.

Slanger, E., & Rudestam, K.E. (1997). Motivation and disinhibition in high risk sports: Sensation seeking and self-efficacy. *Journal of Research in Personality, 31*, 355-374.

Spielberger, C.D., Gorsuch, R.L. & Lushene, R.E. (1970). *STAI: Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologist Press.

Sport & Recreation New Zealand. (2009). *Sport and Recreation Participation Levels: Findings from the 2007/08 Active NZ Survey*. Wellington: SPARC.

Stöppler, M.C. (2003). *Cortisol: The "Stress Hormone"*. Retrieved from http://stress.about.com/library/weekly/aa012901a.htm

Tabachnick, B.G. & Fidell, L.S. (2001). *Using Multivariate Statistics* (4^{th} ed.). Boston: Allyn and Bacon.

Takai, N., Yamaguchi, M., Aragaki, T., Eto, K., Uchihashi, K. & Nishikawa, Y. (2004). Effect of psychological stress on the salivary cortisol and amylase levels in healthy young adults. *Archives of Oral Biology, 49*, 963-968.

Takahashi, T., Ikeda, K., Ishikawa, M., Tsukasaki, T., Nakama, D. Tanida, S. & Kameda, T. (2004). Social stress-induced cortisol elevation acutely impairs social memory in humans. *Neuroscience Letters*, *363*, 125-130.

Weber, C.S., Thayer, J.F., Rudat, M., Sharma, A.M., Perschel, F.H., Buchholz, K., & Deter, H.C. (2008). Salt-sensitive men show reduced heart rate variability, lower norepinephrine and enhanced cortisol during mental stress. *Journal of Human Hypertension 0,* 1-9

Weinberg, R.S. & Gould, D. (2007). Foundations of Sport and Exercise Psychology (4^{th} ed.). Illinois: Human Kinetics.

Weiten, W. (2004). *Psychology: Themes and Variations*. Australia: Thomson Wadsworth.

White, J.M. & Mattson Porth, C. (2000). Physiological measurement of the stress response. In V.H. Rice (Ed.), *Handbook of Stress, Coping and Health: Implications for Nursing research, Theory and Practice* (pp. 69-96). Thousand Oaks: Sage Publications, Inc.

Zuckerman, M. (1983). Sensation seeking and sports. *Personality and Individual Differences, 4,* 285-293.

Zuckerman, M. (1990). The psychophysiology of sensation seeking. *Journal of Personality, 58*, 313-345.

Zuckerman, M. (1994). *Behavioural Expressions and Biosocial Bases of Sensation Seeking*. New York: Cambridge University Press.

Zuckerman, M. (2000). Are you a risk taker? *Psychology Today, 33* (6), 52-87.