EVALUATION OF VIGILANCE IN SUBJECTS EXPOSED TO COMPLETE SEATED INVERSION BODY POSTURE

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Evaluation of vigilance in subjects exposed to complete seated inversion body posture

By

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ABSTRACT

The seated inversion posture is reported as being useful in evaluating potential effects of gravitational force on the upper body versus that of the lower body. The seated inversion posture is useful in simulating the environments that astronauts are exposed to in microgravity conditions as well as environments that humans may be exposed to during normal daily routines. Many recreational and labor related inverted positions occur in the air, outer space, as well as on or under water. Vigilance is required to complete activities of daily living, extra-curricular activities as in avoidance of and escape from life threatening conditions. Vigilance encompasses the functions of cognition, attention, alertness, and decision making skills that are required to maintain upright posture and balance as well as required to ensure proper accuracy and perception when solving problems. The purpose of this study was to understand the effects of an inverted posture on variables of vigilance, heart rate and blood pressure. Eight males completed 5 sessions of assessment. Heart rate (HR), and blood pressure (BP), as well as vigilance tasks and reaction time were assessed first in a seated upright posture, followed by the seated inverted postures, and again a seated upright posture. Intraclass correlation coefficients for Tower of London (ToL), Selective Attention and Response Competition (SARC), anxiety, Heart Rate (HR), Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) were excellent ($R>0.95$). The inverted condition produced significant ($p<0.0001$) decrements in performance on The Tower of London (ToL) tests and Selective Attention and Response Competition test. Time to completion was significantly slower in (63.4% and 40.7%) the ToL during the inverted condition as compared to the pre and post upright assessments. Reaction time was slower (10.4% and 11.7%) during the SARC tests during the inverted condition as compared to the pre and post upright assessments. No significant changes ($p<0.537$) were found in the Attention Networks Test. SBP ($p<0.0001$), DBP ($p=0.0003$), and HR ($p<0.001$) demonstrated significant decreases during the inverted condition as compared to that of the pre and post conditions for the ToL. Similar results for SBP, DBP and HR were observed in all tests of vigilance (SARC and ANT) in the inverted condition. During the inverted condition participants reported a feeling of anxiety 25% higher than the pre-inversion condition and 51% higher than the post-inversion condition.

Key Words: Vigilance, inversion, inverted seated posture, microgravity, head down tilt, cerebral blood flow,

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ANT	Attention Network Test
ARS	Anxiety Rating Scale
BP	Blood Pressure
CBF	Cerebral Blood Flow
DBP	Diastolic Blood Pressure
ECG	Electrocardiogram
HDT	Head Down Tilt
HR	Heart Rate
HUT	Head Up Tilt
MVC	Maximum Voluntary Contraction
PAR-Q	Physical Activity Readiness Questionnaire
SARC	Selective Attention and Response Competition
SBP	Systolic Blood Pressure
SST	Squat-Stand Test
TCD	Transcranial Doppler

ToL	Tower of London
VO2	Volume of Oxygen Consumption

CO-AUTHORSHIP STATEMENT

There have been substantial contributions to this manuscript by a number of key individuals.

i) The ANT data was collected using the Superlab software supplied and installed by Dr. Jim McAuliffe of Nipissing University in North Bay Ontario. Dr. McAuliffe also provided some data analysis of the ANT data as well.

ii) The heart rate data was analysed by Dr. Michel J. Johnson of the Universite de Moncton

iii) With the contribution and direction of Dr. David Behm I prepared the following thesis.

Chapter 1

Introduction

1.1 INTRODUCTION

The human species has adapted to the upright posture that humans perform in daily function. It is uncommon for humans to experience inverted postures. Extreme tilt or complete inversion positions may be experienced with accidents such as overturned or submerged helicopters, motor vehicles, or boats such as kayaks. Persons involved in such situations need the opportunity to assess their situation and develop a plan of action. Escape and survival will necessitate the interaction of force (physical) and vigilance (mental). The only two studies investigating complete seated inversion postures demonstrated decreases in force, indicating inversion-induced impairments to the neuromuscular system (Paddock & Behm 2009, Hearn et al. 2009). These studies highlighted inversion-induced decrements to neuromuscular performance but there are no studies examining inversion effects on mental processes. It has been speculated that complete inversion effects vigilance and cognition due to increases in intracranial, and orbital pressures as well as decreases in blood pressure and heart rate. No studies to date have examined these speculations.

Vigilance or level of alertness is important in every function of daily life. Cessation of alertness results in sleep or unconsciousness while increased alertness can result in sleep deprivation or insomnia (Rosekind & Gregory, 2010). Variables of vigilance including perception are adjusted with our heightened or weakened senses of sight, hearing, taste, smell, and touch. The interaction of the physiological systems such as the vestibulo-ocular system which helps the body balance, coordinate and communicate with the brain producing coordinated movement (St. James et al. 2005). A second variable of vigilance is that of cognition. Cognition not only includes the act of pondering, but also includes problem solving, reaction time and the time required to complete a thinking task (St. James, Schneider, & Eschman, 2005). As vigilance is vital for survival in life threatening accidents and important for optimal work performance, it would be important to investigate the effects of inversion upon these processes. Inversion-induced inhibition of heart rate and blood pressure suggest decreases in sympathetic stimulation of the nervous system (Hearn, Cahill & Behm 2009 and Paddock and Behm, 2009). Induced increases in arterial pressure in the upper body and head resulting from inversion have been observed as negligible in their relationship with cerebral blood flow (CBF). Heistad & Marcus, 2012 suggest that the activation of baroreceptors due to the increases in arterial pressure, results in no change to total or regional CBF in dogs. The consequences of neuromuscular and cardiovascular inversion-induced impairments for cognitive and vigilant performance have not yet been investigated.

Extended research is therefore required to understand the effect of inverted postures on physiological functions. The objective of this study was to examine vigilant, heart rate and blood pressure responses to seated upright and inverted postures.

1.2 PURPOSE AND HYPOTHESES

The purpose of this study was to understand the effects of an inverted posture on variables of vigilance, heart rate and blood pressure.

Three experimental hypotheses were proposed:

H1: A decrease in vigilance (cognition and perception decision making and reaction time) measures will be seen with inverted compared to upright positions.

H2: Inversion will induce decreases in heart rate and blood pressure.

1.3 LIMITATIONS

The following limitations are recognized in this study:

1. The study included a small sample size (n=8).
2. The study includes only males.
3. The duration of time participants were exposed to the inverted seated condition was small (n<2min).

Chapter 2

Review of Literature

2.0 ABSTRACT

Although it is uncommon for humans to perform daily functions while inverted, such scenarios exist in sport (gymnastics), work (military pilots) and emergencies (overturned vehicles and other craft). The only two studies investigating this posture have shown impairments to muscle force and activation. There were also decreases in cardiovascular measures such as Heart rate and blood pressure, which may signify an inhibitory effect on the sympathetic nervous system. It is unknown what effects inversion has on vigilance functions. Related research investigating head down tilt and microgravity could provide insights. Some of the mechanisms that might adversely affect performance could be related to changes in cerebral blood regulation, vestibule-ocular reflexes, spatial orientation, parasympathetic / sympathetic excitation, and afferent excitability of spinal motorneurons.

2.1 INTRODUCTION

Humans must adapt to many different environments during work and play. Many of these environments pose potential health hazards or can impair performance. There has been voluminous work published on the physiological effects of hypoxic, hyperbaric, hypobaric, hypothermic, hyperthermic and other environments experienced by humans. Humans spend a predominant portion of their waking hours in an upright position. In contrast very little research has examined the effects of inversion on human physiology and performance. An inverted position can be adopted during emergencies such as overturned vehicles and aircraft as well as during work and sport (i.e. gymnastics) situations. The only two published studies examining the effects of full inversion on humans (Paddock and Behm 2009, Hearn et al. 2009) reported neuromuscular and cardiovascular changes that could impact safety and performance.

Paddock & Behm (2009) examined muscle activation and force in an inverted seated position to observe the neuromuscular responses. Observations demonstrated a relationship between the inverted seated position and decreases in maximal voluntary contraction (MVC) and instantaneous strength. Similarly in experiments conducted by Hearn et al. (2009) the inverted seated position resulted in significantly lower MVC force, rate of force development, and biceps brachii EMG activity. The inverted seated position was also observed to produce significant decreases in heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP) in both experiments. Thus both studies observed decrements in neuromuscular function with an inverted seated position. Both articles hypothesized that the neuromuscular changes may result from inversion induced changes in the sympathetic nervous system as demonstrated by decreases in heart rate and blood pressure. However, there are no studies examining the effects of inversion on cognitive or vigilant functions. Impairments in cognitive and vigilant functions in concert with neuromuscular deficits would dramatically impact an individual's ability to escape from a threatening inverted situation such as overturned vehicles or helicopters.

As there are only two published studies that observe effects of inverted posture on physiological functioning, other related postures such as head down tilt studies may provide some understanding of probable inversion-induced physiological alterations. The purpose of this literature review is to examine related literature related to vigilance and investigate observed conditions that have demonstrated effects that alter vigilance.

2.2 VIGILANCE

Vigilance has been identified and defined in scientific literature since the late 1800's. William James, American philosopher and psychologist identified the concepts of vigilance and attention. He recognized that attention is centrally focused however may be affected or inhibited by peripheral diversions. Head (1923) identified vigilance as "the extent to which the activities of a particular portion of the central nervous system exhibit at any moment signs of integration and purposive adaptation." The definition of vigilance has evolved over the decades to include response time, accuracy, and decision making (Chern Pin-Chua et al., 2012). Cohen (1993) interpreted attention as a multifaceted feature of the brain incorporating sections of the brain responsible for the integration of sensory information, cognitive processing and movement.

Vigilance testing and knowledge of factors, which impair vigilance, are crucial to industries such as air traffic control, inspection and quality control, automated navigation, military, border surveillance, and lifeguards. Measurement of vigilance in the research setting generally includes the correct identification or consistent identification of a stimulus. Davies & Parasuraman (1981), defined commission errors as those committed when a stimulus has been incorrectly reported and omission errors are those which involve the failure to identify a stimulus. Vigilance measurement also includes assessment of reaction time, or the amount of time required to observe and identify a stimulus, process and discriminate the stimulus and facilitate or make a decision regarding the appropriate reaction (Davies & Tunes, 1970). Ballard (1996) described three categories of factors that affect vigilance performance. Task parameters, environmental or situational factors and subject characteristics may all influence vigilance performance in humans. Button (2003), suggested that common tasks of vigilance require multi-tasking often occurring in conjunction with elements of physiological stress. Physiological stresses were also suggested to disturb state of arousal, motivation, capability to allow and process presenting stimuli as well as the ability to anticipate a stimulus.

In 1950, Norman Mackworth published his findings regarding the interruption of vigilance through extended visual search. His curiosity was motivated by discoveries during World War II indicating near misses or misses of important events near the end of shift by radar and sonar operators. From these findings Mackworth described the Inhibition Theory. This theory described as "a decrement in vigilance…an extinction of the conditioned response when that response is no longer reinforced." The inhibition theory speculates that an operator's reaction to events or stimulus may decline over time, while the number of responses may remain relatively stable.

The expectancy theory, first presented by Baker (1959) suggests that observer's expectations concerning signal events frequently vary from actuality, and this incongruity represents the reaction outcomes acquired in vigilance research. The theory includes that observers modify their level of reactions grounded on their perceived signal occurrence and past experience with that task.

Hebb (1955) presented his arousal theory based upon the work of prior researchers Yerkes and Dodson (1908). Hebb suggests that an operator's vigilance is dependent on their level of arousal, and that reductions in presentation are an outcome of reduced stimulation from a less stimulating environment in which the vigilance task presents. Frankhaeuser et al., (1971) contend this arousal theory does not represent the amplified stress levels observed with vigilance tasks. Research proposes that vigilance is connected with high levels of catecholamines (Frankenhaeuser et al., 1971). These catecholamine's are released by the endocrine system's response to stress. Catecholamines are highest at the onset of vigilance tasks, in anticipation of their occurrence. In response to criticism regarding the arousal theory, the resource theory evolved (Kahneman, 1973; Moray, 1967; &, Norman & Bobrow, 1975). This theory suggests that an operator's vigilance is reliant on the mental capabilities or resources that can be recruited to complete the task. Parasruaman et al. (1987) suggested that decreased measures of vigilance resulted from the inability for demand of mental resources to be met during vigilant tasks.

Broadbent (1958) suggested that information that enters the brain experiences filtering as it is processed to the higher centers. Later theories evolved from the filter premise suggested that information entering the brain is first filtered for unwanted information and secondly for meaning. This double filter theory postulated that if the meaning of the information was solid enough it would rise to the conscious (Triesman, 1964). In 1976, this double filter theory evolved to one of semantic pertinence (Norman & Bobrow, 1975). This theory of pertinence yielded that information processed to the brain was filtered for semantics and pertinence of the semantics. This idea of pertinence further determined the importance of the information processed thereby stimulating the acceptance or ignorance of it.

The arousal, resource, filtering, and pertinence theories all lead to the development of the limited capacity theory (Norman & Bobrow, 1975). The investigators recommend that humans are only able to absorb and process restricted volumes of information and stimuli. The many theories and their evolution suggest that vigilance is dependent upon the volume of information required by the tasks, as well as any interfering information or stimuli that may be present. Different environments (i.e. instability, darkness) and postures (inversion) may interfere with the absorption and processing of information and stimuli, thereby limiting vigilance capacity.

Seated inversion elicited a number of physiological responses to the neuromuscular and cardiovascular systems that may be related to changes in sympathetic responses (Paddock & Behm 2009, Hearn et al. (2009) Since inversion may alter central and peripheral nervous system functioning, it is conceivable that sensory or motor components of vigilance could also be adversely affected. This possibility has never been directly investigated. As there are only two studies investigating inversion effects other related studies may provide insights. For example, increases in intracranial pressure resulting from the effects of gravity with an inverted position may alter the central and peripheral nervous system responses.

2.3 RELATED RESEARCH

2.3.1 TILT STUDIES

Tilt tables are used in the medical, rehabilitation, and research environments. Tilt tables are available to provide variations to the standard upright, seated and supine postures that human's exhibit daily. Experiments and treatment associated with the condition of head up tilt commonly examine causes of unexplained fainting (syncope). The tilt table in these experiments permits researcher to observe and compare vascular hemodynamics and heart rate variability during changes in posture from supine to upright (Holmegard, et al., 2012). Perry (2010) reports that tilt testing is the definitive examination for the disorders of orthostatic hypotension and vasovagal syncope. Tilt testing permits researchers to observe a neutrally-mediated reflex in a fixed environment. Lacoviello et al., (2010) concluded that decreased sensitivity of the baroreceptors during head up tilt is valuable in its ability to predict the reoccurrence of syncope in patients. Several studies have shown that cerebral oxyhemoglobin concentrations decrease while in head up tilt position (Kurihara et al. 2003). On the other hand similar experiments have also reported no effect of postural stress on cerebral oxyhaemoglobin (Masdent et al.1995, 1998; Colier et al. 1997; Mehagnoul-Schipper et al. 2002).

Head down tilt (HDT) also known as the Trendelenburg position has been used in the medical, rehabilitation and research environments. Variations of this position have been used as a technique for peritonisillar abscess drainage, spinal anaesthesia, hypovolemia, and are especially useful for trauma and accessing the pelvis. In many investigational situations, HDT facilitates the pooling of blood in the brain. It is assumed that the larger the angle of tilt the greater the effect of gravity pulling blood towards the head creating a lower body pressure in the lower extremities.

Thornton et al. (1987) and Hargens et al. (1983) discussed that during HDT participants experienced a cephalic fluid transfer, increasing in the upper portion of the body that is characterized by facial edema, nasal congestion, and disrupts the hemodynamics of the head. This exposure to HDT can help to simulate the conditions of microgravity on earth, helping us understand and train for outer space. Grenon et al. (2005) reported that both microgravity and simulated microgravity (HDT) produce alterations to orthostatic tolerance, the autonomic nervous system, and the volume regulating system. HDT helps us simulate the potential pooling of blood in the head and brain region. Similar physiological responses may be present with microgravity allowing further insight into inversion effects.

2.3.2 MICROGRAVITY

Travel away from the earth's unique force of gravity has exposed evidence of physiologic alterations challenging humans ability to explore the universe (Kramer et al., 2012). While in space astronauts experience weightlessness compare to the 1*g* gravitational force that the human body has adapted to on earth. Microgravity and simulated microgravity (HDT) induce deconditioning of the human physiological systems. Microgravity induces a fluid shift toward the upper body. This increase in fluid to the upper body results from fluctuations in the hydrostatic pressure gradient. These fluctuations yield distinguishing indicators of facial edema, nasal congestion and headache (Thornton et al., 1987).

The first cardiovascular alterations were observed by Bondar et al. (1991). A 30% increase in cerebral blood flow velocity was measured during parabolic flight using a transcranial Doppler (TCD) technique. The negative effects experienced by the cardiovascular system due to microgravity are decreases in blood circulation, interstitial fluid volumes, arterial blood diastolic pressure, ventricular stroke volume, and decreases in estimated left ventricle mass (Heldt, 2002). Antonutto & di Prampero (200) suggest that deconditioning of the cardiovascular system can also reset the carotid baroreceptors. These negative effects manifest themselves mostly upon re-entry into earth or return to upright position after bed rest in the simulated environment.

Peterson et al. (2002) specified that tilt table reproduction of microgravity distresses the cardiovascular system with shifts from upright to supine necessitating acute circulatory compensatory mechanisms with quick commencement of simulation. The reduction in heart rate and escalation in the stroke volume of the left ventricle was also observed by Linnarsson et al. (1996). Carotid baroreceptors primarily and to a smaller degree the cardiopulmonary volume receptors fuel the compensatory response. The surge of stroke volume is activated by the Frank-Starling mechanism, and the venous return is enlarged due to the transfer of blood to the upper body from the lower body, resulting from pooling during hypergravity.

The Skylab 4 flight of 1973 spent 84 days in space and precautions were made to attempt to prevent cardiovascular deconditioning. A shift in body (cephalad) fluids from the head to the thorax, overwhemlming the crucial vasculature of the cardiovascular system volume sensors to perceive overload. The cardiovascular neuroendocrine system was forced to adapt and make modifications to decrease total peripheral resistance, heart rate and cardiac intropism and to decrease circulatory volume due to the increase in water excretion of the kidney. The kidney is informed by the altered circulating hormones and the decrease of sympathetic tone of its arterioles that neural adaptation is needed.

Shibasaki et al. (2003) tested the effects of aerobic exercise training during microgravity conditions on thermoregulatory responses. Decreased plasma and blood volume and aerobic capacity are connected with impaired thermoregulatory responses observed during exercise and passive heating after head down body tilt exposure. Results indicate that dynamic exercise during short periods of HDT bed rest preserves thermoregulatory responses. Head down tilt bed rest, peak oxygen uptake and plasma and blood volumes were not different relevant to pre-head down tilt bed rest values.

Exposure to simulated microgravity testing the magnitude of reduction in plasma volume and work capacity depended on the initial level of aerobic fitness, and peak oxygen uptake. This testing demonstrated a larger reduction in VO2 peak that unfit subjects thereby associated with larger reductions in plasma and blood volume (Convertino, 1998).

Convertino (1998) suggested that in contrast to the values of Shivasaki et al. (2003) reductions in plasma volume and blood volume were observed under simulated microgravity conditions. Although testing two different responses, the responses are related in that they observe the same mechanisms for modification. Convertino (1998) suggests that the magnitude of physical deconditioning induced by exposure to microgravity without measures of countermeasures was influenced by the initial fitness of the subjects tested.

In microgravity the cerebrum will not contend with the force of gravity pulling blood away from the head. During simulated microgravity, investigations into the effects of postural changes on cerebral oxygenation yielded that oxyhemoglobin and the Tissue Oxygenation Index decreased in postural change from supine to head up tilt (Kurihara, Kikukawa, & Kobayashi, 2003). The Tissue Oxygenation Index is a novel monitoring indicator derived by near-infrared spectroscopy, implemented by Matcher et al., (1995), Suzuki et al., (199) & Kurihara et al. (2003) and other investigators or cerebral function. Masden et al. (1998) produced similar results to that found by Kurihara et al., in that insignificant amounts of change were observed in cortical oxygenation. Increases in heart rate and blood pressure were observed similar to that seen by Smith and Port (1991). Hence, microgravity research indicates that the human physiological responses to low gravity tend to be sufficient to overcome alterations in cerebral blood flow.

Countermeasures to help delay and or prevent the onset of microgravity deconditioning, consist of on board physical exercise of cycloergonometric and or treadmill exercise for at least 2 hours per day, the utilisation of special elasticised suits, providing passive stress to the antigravity muscles of the legs and torso, lower body negative pressure devices and or the ingestion of water and salt tablets just before the shuttles re-entry and landing (Antonito, and Di Prampero, 2003).

2.4 POSSIBLE MECHANISMS FOR ALTERATIONS IN VIGILANCE

2.4.1 CEREBRAL FUNCTION

Normal upright posture of humans dictates the downward flow of blood from the heart into the extremities. Transfer from the supine position to upright position commonly induces orthostatic hypotension or a sudden decrease in blood pressure. The complete inversion of the body in seated position negates the normal gravitational pull of blood to the extremities redirecting it to the upper torso and head region as they are closest to the ground in this position. How does this influx of blood to the head and brain affect the functioning of the brain?

The cerebrovascular system supplies the brain with blood flow required for normal brain function. The oxygen requirements of the brain surpass all other organs except the heart. Receiving approximately 20% of cardiac output, the brain consumes 20% of the body's oxygen (Diringer, M., 2008). The research suggests that interruption in cerebral blood flow (CBF) results in cerebral dysfunction and ultimately unconsciousness when disruption of CBF is prolonged. Diringer, (2008) also suggests that permanent brain damage is imminent with four to six minutes of complete disruption of blood flow.

Hypoxia or decreased tissue oxygenation due to changes in the delivery and utilization of oxygen to the cells are directly affected by CBF (Price, S., & Wilson, L., 2003). Hypoxia is commonly imposed with changes in atmospheric pressures (mountain climbers, deep sea divers), carbon monoxide poisoning (fire entrapment, unsafe working conditions), in cases of severe anemia, or in situations in which there is failure to oxygenate the blood (Porth, 2002). Decreased oxygenation of brain tissues produces a depressant effect on the brain and its function. Chronic hypoxia has shown that neurons are capable of substantial anaerobic metabolism, yet produces effects of euphoria, listlessness, drowsiness, and impaired problem solving (Porth, 2002). An inverted position may have to contend with the opposite effect of increased blood flow and pressure. Rabbits exposed to head down tilt variations of 45^0 and 75^0 demonstrated changes in cerebral blood flow and somatosensory-evoked potentials (Asai et al. 2002). No significant changes in one hour were observed in relation to the parietal cortex at 45^0 of Head Down Tilt (HDT). However, at the end of one hour of HDT at 75^0 cerebral blood flow progressively decreased, while no changes were observed yet again in the somatosensory-evoked potentials.

Bonder et al. (1995) and Kawai et al. (1993), experimented with the velocities of cerebral blood flow under conditions of parabolic flight and/or HDT, and found that cerebral blood flow increases over time in both conditions. According to Kawai et al. (1996) HDT elevates the oxygenation of the brain tissue and cerebral blood flow, but Satake et al. (1994) experimented implementing a single photon emission computer tomography analysis that depicted the basal ganglia and cerebellum as the recipients of the increased cerebral blood flow in contrast to that of the cerebral hemispheres. Differences in experimental protocol of measurement, times and duration of HDT have been linked to the discrepancies in results.

The effects of 10^0 (acute) HDT on cerebral auto regulation was investigated, applying the Valsalva maneuver inducing sympathetic withdrawal, thereby facilitating transfer function gain between arterial blood pressure and cerebral blood flow (Cooke, Perllegrini, & Kovalenko, 2003). The transfer function gain quantifies the relationship of change in the arterial blood pressure as a function of the change in cerebral blood flow or vice versa. Cooke et al. (2003) hypothesized that HDT (another maneuver resulting in sympathetic withdrawal) will increase the transfer function gain between arterial pressure and cerebral blood flow velocities, defining the effects of acute HDT on cerebral autoregulation.

In agreement with the results of Cooke (2003) Satake et al. (1994) found that 10^{o} HDT did not affect cerebral blood flow. Satake et al. (1994) and Kawai et al. (1996) both used the tilting positions analogous with microgravity at -6^{o}, however Kawai et al. (1996) found an increase in cerebral blood flow. However, there are discrepancies on the effects on cerebral blood flow, cerebral blood volume and intercranial pressure (Lovell et al., 2000 & Keil et al., 1992). Hannerz (2004) observed increases in cerebrospinal fluid pressure, extracranial blood volume and decreased intracranial blood volume during HDT.

2.4.2 CEREBRAL BLOOD FLOW REGULATION

Regulation of blood flow to the brain is crucial. An abundance of research exists regarding the effects of decreased blood flow to the brain, however little is known about the effects of pooling of blood in the brain or orthostatic hypertension. Carey et al. (2003) defined cerebral autoregulation as "the inherent ability of cerebral blood vessels to keep cerebral blood flow constant over a wide range of perfusion pressures." (p.1871) Singh & Stock (2006) discuss the strict regulation of cerebral blood flow to supply the brain's metabolic needs. Increased blood flow to the brain (hyperemia) can lead to an increase in intracranial pressure, which can injure brain tissue and affect brain function (Kandel, 2000). LeLorier et al. (2003) observed that exposure to five minutes of 60 degree HUT results in stress on the hemodynamics resulting from a decrease in venous return, stroke volume and blood pressure. The researchers suggest that the gravitational effects of the transfer from the supine position to the 60^{0} HUT position induces a significant change in hydrostatic pressure. Changes in the efferent carotid baroreceptors influence alterations in hydrostatic pressure in the carotid bodies.

Cerebral autoregulation was preserved in the presence of decreased sympathetic neural activity. These results were previously seen by Cooke & Dowlyn (2000) and Tenaka et al. (1999). They continued to define the transfer of fluid location to the upper body, as one of the factors responsible for the sympathetic withdrawal in addition to that of the loading of the baroreceptors. A correlation is observed between the arterial pressure overshoot after the release of strain from the Valsalva maneuver to the magnitude of sympathetic traffic that preceded it. Similar results were found by Cooke (2003). and Smith et al. (1996). The suggestion that inversion induces a sympathetic inhibition may be similarly related as the increased cephalic blood pooling and pressure can lead to an inhibitory rebound effect decreasing sympathetic stimulation. It was detailed that baroreceptor activation and the inhibition of the sympathetic nerve activity were correlated to the arterial pressure oscillations observed by Pagani et al. (1997) and Wallin & Nerhed (1982). These articles justify Cooke's overshoot results which demonstrated that HDT decreased systolic blood pressure overshoot increasing the cardiovagal baroreflex gain. Autonomic neural modulations of dynamic cerebral autoregulation were suggested to influence mild physiological manipulation of autonomic activity with acute HDT. Yet, manipulation of cerebral autoregulation had no effect on the cerebral vasculature's ability to regulate constant blood flow. More study is needed in the interactions between the effects of HDT on other modulators of the cerebral autoregulation. Kitano et al. (2005) investigated local blood flow regulation during orthostatic maneuvers, finding that the vascular responses in the limbs due to the cardiopulmonary and arterial baroreflexes can be strongly induced by gravitational effects. It was also inferred that during head up tilt, peripheral vascular responses in the lower limbs are augmented, presumably by local mechanisms specifically induced in the dependent limbs. Inducing increased blood flow to the upper body and head through complete seated inversion may increase blood flow to the brain. This increase in blood flow may in turn increase the accessibility and delivery of oxygen to the brain. However the HDT studies that showed tight cerebral blood flow regulation and sympathetic inhibition in response to an arterial pressure overshoot may suggest that inversion-induced cerebral blood flow increases may be compensated or balanced by cardiovascular responses (i.e. decreased heart rate, blood pressure, increased peripheral vasodilation).

Orthostatic intolerance is common post space flight for most astronauts. Blaber et al. (2011) suggests that cerebral autoregulation is compromised by the effects of gravity. This interruption to cerebrovascular conductance compromises the conservation of a constant level of perfusion. Njemanze (1992) specifies that typical cerebral perfusion of the brain is compulsory to preserve brain tissue and activity of cortical neurons.

2.4.3 VESTIBULO-OCULAR REFLEX

Whereas cerebral blood flow changes with inversion may be compensated other neural processes may adversely affect vigilance and cognitive functions. Cerebral functions of the brain control the body's physiological processes, responses and adaptations to altered stimuli and environments. Haslwanter et al. (1996) attempted to quantify the total vestibule-ocular reflex performance in humans. Halswanter et al (1996) reported that with normal vestibulo-ocular reflex activity, the eye rotation speed must equal that of the head speed; the eye rotation axis must be aligned with but directed opposite to the head rotation axis. Therefore the eye velocity must be in synchronicity with the head velocity. Disruptions with the direction and or magnitude of these dimensions may result in a retinal slip. Haustein, (1989) and Tweed et al. (1990), both agreed with Halswanter's(1996) qualification and technique procedures to produce results from three dimensions.

The angular vestibule ocular reflex is activated when the head is rotated, generating counter rotation of the eyes in the orbit (Yakushin et al. 2003). From a geometric point of view the angular vestibule-ocular reflex is manipulated to stabilize retinal images during three dimension head rotations (Halswanter et al. 1996). Studies on both humans and animals reflect that the gain of the angular vestibule-ocular reflex may not accurately compensate for head rotations in dark environments. Yakushin also details that the angular vestibulo-ocular reflex can be adjusted by increasing or decreasing the gain, in order to be more precise.

Findings infer that when the gain of the vertical angular vestibule ocular reflex was altered with upright or side-down positions, maximal increasing changes occurred when the animals were tested in the head orientation in which the gain was adapted, and the changes decreased continuously as the head was deviated from this orientation. The gravity-dependent gain modifications are similar to those yielded in earlier experiments (Yakushin et al. 2000). The quantity of gravity-dependent gain changes revealed following dual-state adaptation was generally similar to those yielded following single-state adaptation. Gravity specific changes in gain are therefore alterations in reaction to angular vestibulo-ocular reflex variation to the direction of the head movement of the three dimensions. It was concluded that orientation to gravity was fundamental in the adaptation of the angular vestibule-ocular reflex, satisfying a considerable position in term of the modified gains.

Telford et al. (1998) studied the interactions between the semicircular canals and the otolith functions on the vestibulo-ocular reflex and its influence on fixation distance. To understand the control of natural head movements, the angular and the linear vestibule ocular reflex components which produce the vestibule-ocular reflex are mediated by the semicircular canals and the otoliths. This mediation compensates for head movements while maintaining binocular fixations on targets in space. The recording of binocular eye movements resulted in an activated angular vestibule-ocular reflex during eccentric rotations with the head centered about the angular vestibule-ocular reflex. The linear vestibule-ocular reflex component was derived from the interaural or dorsoventral tangential accelerations, depending on whether the head was facing up or right side down.

Kondrachuk (2003) observed eccentric rotations of the head, while facing nose out (facing away from the axis of rotation) gave rise to both angular vestibule-ocular reflex and linear vestibule-ocular reflex components of the ocular response in the same place and direction (coplanar and synergistic). It was determined that response magnitudes increased with increased vergence. The opposite test with nose facing in (facing the axis of rotation) again had both angular vestibulo-ocular reflex and linear vestibule-ocular reflex components but directed oppositely (Wearne, 1999). It seemed that the angular vestibule-ocular reflex dominated in response when the fixation distance was far. The closer the fixation, the responses declined to almost none. When the fixation distance continued to approach even further, the linear vestibule ocular reflex component was more predominant and the response phase inverted. A number of researchers agree that the synergistic stimulation of the angular vestibule-ocular reflex and the linear vestibule-ocular reflex are found to enhance ocular responses relative to the angular vestibule ocular reflex alone (Aw, et al., 1996).

On the other hand all researchers tend to agree that the antagonistic coplanar canal-otolith stimulation reduces the intensity of the response related to only the angular vestibule-ocular reflex (Angelaki, et al., 2002). The observed linearity of angular vestibulo-ocular reflex/linear vestibulo-ocular reflex interactions in squirrel monkeys conflict with that of a similar study in humans (Anastasopoulos et al. 1996). Methodological differences primarily with the use of humans have been attributed to the conflicting results. Larger stimulus and lack of direct measurements of vergence may also produce differing results. Hence, the increase of the angular vestibulo-ocular reflex can be undesirably affected by tilt altering the perception of verticality, positioning of retinal images and control of head movements, all of which can negatively affect vigilance performance.

2.4.4 SPATIAL ORIENTATION

The perception of spatial vertical quantifies and monitors the normal responses of the vestibule ocular system, as one of the many functions associated with spatial orientation. Aubert (1861) studied the human ability to adjust a luminescent line to a position of verticality with considerable accuracy as long as the head and body were erect, thus hypothesizing the effects of tilt. Aubert (1861) found that when the same subjects using the same experimental protocol produced constant error with the addition of head tilt and concluded that body tilt influences the perception of vertical. A number of experiments have been performed concerning the changes in perception of vertical as a result of body tilt. Most of these studies however have been limited to visual perception of verticality. An experiment on the effect of body tilt on the tactual-kinesthetic modality of perception of verticality versus the visual perception of verticality was exhibited by Bauermeister et al. (1964). The early experiment systematically studied the effect of body tilt on tactual-kinesthetic perception of verticality. This methodology assesses apparent verticality using a tactual-kinesthetically adjusted object. Bauermeister et al. (1964) yielded that as body tilt increases so does the perceived displacement of the object from actual vertical position in body tilt positions up to 70^{0}.

"Independent of whether one or two hands were used, increased body tilt led to changing deviations of apparent from objective vertical which were a non-linear function of degree of tilt: with body tilt increasing to approximately 70^{0}, there were increasing displacements of apparent from objective vertical opposite the direction of body tilt; with further increasing tilt up to 90^{0}, this tendency was reversed." (Bauermeister, Werner, & Wapner 1964). Additional effects observed as changes in the amount of body tilt increased were observed with respect with the hand used to demonstrate the perception. "Adjustments with the left hand were located to the right of the adjustments using both hands, and adjustments using the right hand were located to the left of the adjustments with both hands." Thus, body tilt alters the sensitivity of the spatial vertical. Small angles of tilt, perceive the vertical as altered to the side away from the tilt. While using larger angles, presents the vertical shit toward the side of tilt (Aubert, 1861).

Dai et al. (1991) provide insight into research regarding the programming of spatial vertical, in reference to the force of gravity. The subjects all exhibited this programming to retain spatial orientation in addition to the motor responses to vestibular, visual, and somatosensory stimuli. Dai's study (1991) also featured several techniques demonstrated by other experimenters to assess the accuracy of estimating spatial vertical. These articles all set their bodies vertical, when tilted with an accuracy of within 5^{0}. The degree of initial tilt, the duration, and the speed of return, all affect the accuracy of estimation, indicating the precision of spatial vertical within the central nervous system as noted by Dai et al. (1991). Young (1984) as reported by Dai and his colleagues studied the sensors of gravity and programming of spatial vertical inferring that although the otoliths are the most important sensors of gravity, they are joined by the visual and somatosensory system mechanisms in the programming of spatial vertical. Thus in summary, spatial orientation and the ability to recognize the degree of verticality can also be adversely affected by tilt and hypothetically inversion. The inability to correctly diagnose body position would affect the perception, proprioception and response to the external environment.

2.4.5 SYMPATHETIC AND PARASYMPATHETIC NERVOUS SYSTEMS

A number of researchers found decreased systemic sympathetic nervous activity during acute head down bed tilt. Cooke et al. (2000) reported that this acute head down bed tilt had no influence on the parasympathetic activity. Similar studies found that inhibition of the sympathetic activity can decrease heart rate (Sunblad et al. 2000), decrease arterial blood pressure (Bosone et al. 2004; Goodman & LeSage, 2002), and decrease total peripheral resistance (Goodman & LeSage, 2002). While contrasting information indicate daily orthostatic challenges, alternating from sitting to standing position were associated with vagal withdrawal and enhancement of the sympathetic nervous system (Shannon et al. 1987).

The hypothesis is that the regulation of blood pressure during orthostatic challenge and heart rate variability in long term exercise trained subjects can be more successfully maintained. Ueno & Moritani (2003) tested healthy men at rest and during 60^{0} head up tilt, measuring their electrocardiogram (ECG) and blood pressure, suggested that the long term exercise trained subjects demonstrate more efficient parasympathetic responsiveness of the augmented autonomic cardiac modulation. In discussion of the results, the orthostatic stress method evaluates the baroreflex sensitivity in which the sedentary subjects exhibited larger decreases in systolic blood pressure compared to that of the long term exercise trained subjects. The decrease in systolic blood pressure was related to impairment of the baroreflex sensitivity, and/or the large increase in the changing heart rate during the head up tilt in the long term exercise trained individuals. Other studies have indicated that observed decrease in baroreflex sensitivity is associated with increased risk of ventricular fibrillation and cardiac events. In comparison Davy et al. (1997) found no changes in baroreflex sensitivity control of heart rate with exercise training, confirming results of Seals & Chase (1989).

2.4.6 CARDIOVASCULAR ACTIVITY

Changes in posture as a result of tilt inducing acute orthostatic stress demonstrate physiological differences between active and passive variations in tilt. Head up tilt and the active squat-stand test helped Rickards & Newman (2003) determine the difference in the initial cardiovascular responses to these modified postures. Results demonstrated the magnitude of the decrease in initial blood pressure is greater for the squat-stand test versus that seen in the Head up tilt. Head up tilt positioned subjects at only a small deviation from upright at 90^{0}. There were no differences observed in the reflex compensatory response, therefore the squat-stand test dominated the cardiovascular reflexes. To date, physiological differences of the squat-stand test (SST) and the head up tilt (HUT) were established while systematic comparison of the initial circulatory adjustments to our knowledge has not yet been observed. Results indicated fundamentally different cardiovascular responses in the first thirty seconds of each test. This may have occurred because the blood pressure and heart rate are elevated in the upright (SST) in comparison to supine (HUT), in addition to the muscle pump activity in the lower body that compresses leg veins. This compression increases venous driving pressure, forcing greater volumes of blood from the periphery to the heart, increasing total peripheral resistance and venous return, as also reported by Hanson et al. (1995), Lewis et al. (1980), and Rowell et al.

(1986). Borst et al. (1992), Sprangers et al. (1991), Tanaka et al. (1996), all suggest in accordance with the current results that the initial fall in arterial blood pressure upon standing is due to the activation of the cardiopulmonary baroreflexes.

The rise in heart rate in the standing posture may not have been large enough to counteract the decrease in total peripheral resistance, thereby producing an overall decrease in mean arterial pressure, which has also been reported in similar studies by Tanaka et al. (1996), Convertino et al. (1998) and Sprangers et al. (1991). While results from Ueno and Moritani (2003) agree that increases occur in heart rate during head up tilt, and suggest that exercise training may help to counteract the corresponding decrease in systolic blood pressure. Well preserved sympathetic responsiveness in older individuals may aid in arterial blood pressure regulation during passive exposure to induced orthostatic pressures (Vento et al., 2002).

Illamo et al. (2000) agree with the results of Ueno and Moritani (2003) in that higher standard deviation of electrocardiogram R-R interval and coefficient and variation, in long term exercise trained subjects, provides important information on the cardiac autonomic modulation for older adults. Results from conflicting previous studies exhibited no alterations of the baroreflex sensitivity control of the heart rate with exercise trained subjects (Davy et al., 1997; Seals & Chase, 1989). These results indicate that physical activity does not alter the arterial baroreflex sensitivity in young adults (Reiling & Seals, 1988; Vromat et al. 1988), and does not decrease in older adults either (Spina et al. 1994). It is therefore unclear whether short term exercise can attenuate the decrease of the baroreflex sensitivity and autonomic function (Spina et al. 1994; Bowman et al. 1997).

O'Leary et al. (2004) used transfer function analysis to observe the heart rate and vascular reaction to spontaneous alteration in blood pressure from the relationships of systolic blood pressure to heart rate. Using head up tilt, they found that heart rate significantly increased, while no significant changes were observed in blood pressure or total peripheral resistance, and the cerebrovascular resistance index decreased. The relations connecting mean arterial pressure and total peripheral resistance enclose include examinations in conditions of relatively steady state such as head up tilt. It is speculated that the changes in the mean arterial pressure generated the alterations found in total peripheral resistance, also linking stroke volume and total peripheral resistance. These theories confirm the connection of the vascular percentage of the arterial and the cardiopulmonary baroreflexes. Decreases in central blood volume and cardiac filling pressure are induced by the pooling of blood in the lower body due to head up tilt or lower body negative pressure. These orthostatic stresses are known to stimulate increases in peripheral vascular resistance, heart rate that help to maintain blood pressure, mediated by the baroreflex.

Differences were not observed in the vascular resistance of either the arm or the leg during lower body negative pressure (Kitano, 2005). Jacobsen et al. (1992) & Vissing et al. (1989 both reported similar findings, while Essandoh et al. (1986) reported a decrease in blood flow, though much smaller in the calf than the arm during lower body negative pressure. Similar results from Victor & Leimback, and later Rea & Wallin indicate that muscle sympathetic nervous system activity in the legs does increase through lower body negative pressure. As no conflicting information has been found, cardiopulmonary and arterial baroreflex unloading during lower body negative pressure leads to similar magnitudes of vasoconstriction in the upper and lower limbs.

2.4.7 SOLEUS H-REFLEX

Assessments of vigilance include the perception of the environment, processing of the information and subsequent motor actions in response to the environmental cues. Consequently, fluctuations in spinal excitability due to variations in posture could affect vigilant performance. The Hoffman reflex (H-reflex) provides an indication of the afferent excitability of the motoneuron (Trimble and Enoka 1991). Head down body tilt has been demonstrated to affect many of the body's responses, Knikou and Rymer (2003) and Aiello et al. investigating the modulation pattern of the soleus H-reflex in response to imposed static and dynamic changes in body angle, referenced to the vertical plane. They found facilitation of the H-reflex with head down body tilt of 20 degrees and 50 degrees. Dynamic tilting of the body also resulted in H reflex facilitation, indicating facilitation of motoneurons in the soleus muscle independent of altering angular body orientation of movement direction. Knikou and Rymer (2003) also showed the influence of natural stimulation on the vestibular system. In contrast Paquet and Hu-Chan (1999) and Chan and Kearney (1982) investigated the same responses under similar protocols finding decreased excitability in the human H-reflex during dynamic head and body tilts. In further contrast, Trimble (1998) found in altering from supine to vertical body positions, no significant differences were observed. Thus with conflicting results, it is difficult to determine whether inversion would result in an inhibition or a facilitation of afferent excitability of the motorneuron.

2.5 CONCLUSION

To date only two studies have observed the condition of complete seated inversion. These studies have confirmed inversion-induced adaptations to neuromuscular and cardiovascular functioning. HDT offers a comparable environment to the complete seated inversion. Research implementing varying degrees of HDT has shown the induction of changes in cephalic fluid transfer, hemodynamics of the head, orthostatic tolerance, the autonomic nervous system, and the volume regulation system. The change in cerebral blood flow observed in microgravity may also offer comparable understandings of the seated inversion condition. Microgravity induces deconditioning of the human physiological systems. This deconditioning rises from the shift in fluid to the upper body, thereby yielding increases in cerebral blood flow. Decreases in blood circulation, interstitial fluid volume, arterial diastolic blood pressure, ventricular stroke volume and left ventricular mass were also reported observations.

Cerebral autoregulation is relatively efficient but the inversion-induced impairments may still be somewhat attributed to fluctuations in cerebral blood flow. Inversion-induced variations observed with respect to vestibule-ocular reflex, spatial orientation, sympathetic nervous system excitation may possibly provide more concrete contributions to potential vigilance impairments.

Chapter 3

Methodology

3.0 METHODOLOGY

3.1 SUBJECTS

Eight male (172.2 ± 8.4 cm, 88.45 ± 9.6 kg, 21± 4.3 yrs.) recreationally active subjects were recruited from Memorial University of Newfoundland's student population. All participants completed a Physical Activity Readiness Questionnaire (PAR-Q) (Health Canada, Canadian Society for Exercise Physiology 2004), as well as read and signed an informed consent form. Participants had no previous history of any hypertensive or cerebral-related conditions or serious injury. The Memorial University of Newfoundland Human Investigations Committee granted approval for this study.

Intervention

Subjects were instructed to not smoke, drink alcohol, or exercise at least 6 h prior to testing and to not eat food for at least 2 h prior to testing (Health Canada Canadian Society for Exercise Physiology 2004). Subjects received one orientation session introducing them to the apparatus and procedures used in the experiment. There was at least 24 hours recovery between each test session and each subject was tested at similar times of the day for each subsequent session to ensure differences in diurnal rhythms did not affect the results.

Each subject completed 5 sessions after the orientation session. The first 2 sessions were reliability measurements of heart rate (HR), and blood pressure (BP), as well as vigilance tasks and reaction time. The latter 3 sessions had the subjects sit upright to obtain baseline (resting) heart rate and blood pressure measures for 10 minutes, followed by the commencement of the vigilance test under upright conditions. Next under conditions of seated inversion, the vigilance test would occur, followed by a return to an upright position, and completion of the vigilance test. Although the same vigilance test was administered throughout the upright (pre- and post-inversion intervention) and inverted conditions, the different sections of the test could be evaluated and analyzed for each position. After each vigilance test was completed the participant remained in the chair for an additional 5 minutes to ensure the participant had regained pre-test heart rate and blood pressure.

3.2 APPARATUS

A Polar T31 chest strap was secured around the chest of each subject, connected to a Polar s810 (Polar Electro, Finland) receiver watch that was attached to the inversion chair. Subjects were then seated in specially constructed inversion chair (Technical Services: Memorial University of Newfoundland Technical Services), which could tilt subjects at 45^0 intervals, ranging from completely upright, to completely inverted. Once seated in the chair in the upright position subjects were secured into the chair using a 5-point harness system similar to that used in a race car or helicopter. Once secured, a padded attachment was added over the quadriceps to which a desktop holding a laptop computer was placed (Toshiba Satellite A40 System Unit, Toshiba Corporation, China). This laptop administered the tasks of vigilance, using the Psychmate Psychology Software Tools (Psychology Software Tools, Pittsburgh PA), as well as Superlab 4.0 Stimulus Presentation Software (Cedrus Corporation, San Pedro CA). After the desk and laptop were set up and secured an auto inflated blood pressure monitor with a PC interface was placed on the right arm of each subject and programmed to record every minute (AMG Medical Inc., Montreal).

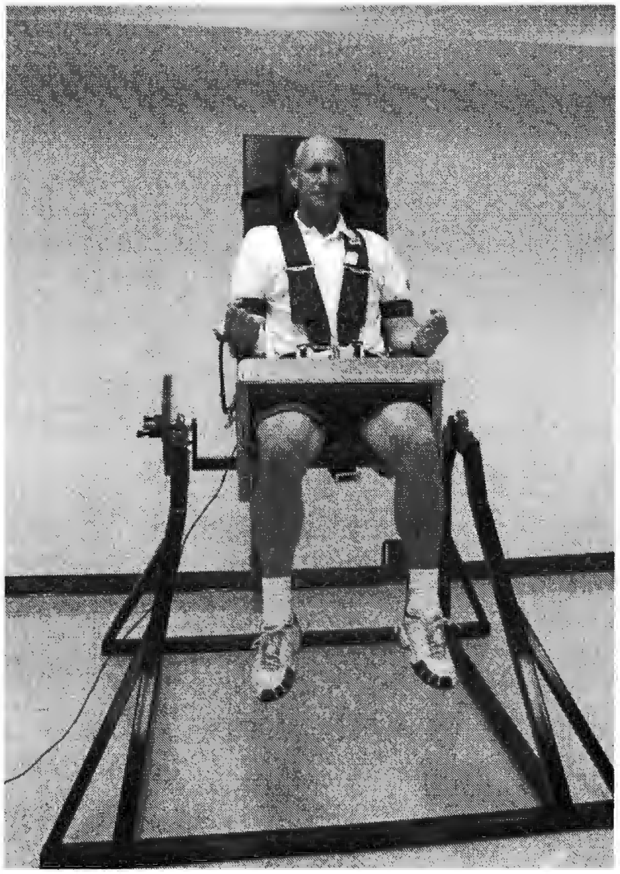

Fig 3.1a Inversion Chair Apparatus demonstrating upright seated posture.

Fig 3.1b Inversion Chair Apparatus demonstrating inverted seated posture.

3.3 DEPENDENT VARIABLES

The Tower of London (ToL) test (Psych Mate Software) is employed to study brain function, and assess executive function, involving problem solving and planning. This variable includes the execution of lower level cognitive processes such as perception, attention and control of action. The Tower of London test has demonstrated an average split-half reliability of r = .718 and a maximum split-half reliability of r = .828 (Caller, Stahl, & Unterrainer, 2012; Schnirman, Welsh, & Retzlaff, 1998). The ToL test features twelve problems for solving with randomized variability of difficulty. Dependent variables for the ToL included number of correct responses and time to complete the test.

The Psych Mate Software also featured a Selective Attention and Response Competition (SARC) test. This test involves focusing on specific stimuli of the environment and the ability to ignore interfering stimuli. Thirty problems are solved during each trial of the testing. Number of correct responses and reaction time were the dependent variables of this specific test.

The SuperLab Attention Networks Test (ANT) test also assesses the dependent variable of executive function as well as that of alerting and orientation. ANT delivers results that specify the effectiveness of the networks that complete the alerting, orienting, and executive (conflict resolution) functions of attention (Fan et. al., 2005). One hundred and forty four ANT trials were presented in reliability and experimental tests of this experiment.

Subjects completed the first 1/3 of the tests upright, and continued to complete the test while being turned into the inverted position where the second 1/3 of the tests were completed. The testing continued through the transition back to upright and the final 1/3 of the tests were completed upright. An average of 140 tests were completed in each trial, the subjects spent between 90-180 seconds in each of the conditions, dependent upon the time required to complete that portion of the tests.

Cox, et al., 1998, developed a concise version of the Competitive State Anxiety Inventory-2 (Martens et al., 1990), referred to as the Anxiety Rating Scale (ARS). This ARS scale was adapted to evaluate precompetitive anxiety and conceptualized the scale ratings in comparison to that used by Borg's (1973) Rare of Perceived Exertion Scale. This short scale permitted the participants in this experiment to evaluate their level of anxiety almost immediately and accurately based upon the descriptors attached to each level of the scale. Prior use of the ARS has grounded the concurrent validity of this assessment (Cox et al., 2000; Cox et al., 1999). This scale demonstrates assessment of cognitive state anxiety, somatic state anxiety and self-confidence.

Participants were given a copy of the ARS upon arrival to the laboratory for reading at every visit. They were prompted at 1 minute intervals to verbally rate their anxiety using the scale, once the methodological protocol had commenced. Prompting for anxiety ratings continued through the pre upright phase, the inversion phase and into the post upright phase.

3.4 STATISTICAL ANALYSIS

Systolic (SBP) and diastolic (DBP) blood Pressure, and vigilance tasks using the Psychmate software data were analyzed using 1 way repeated measures ANOVA. Heart rate data was analyzed using two way repeated measures ANOVA (GB-STAT for MS Windows, Version 7.0, Sliver Springs, MD & Sigma Plot 12 for MS Windows, Chicago IL). The Superlab vigilance data was analyzed implementing the Fan and Posner (Sackler Institute) method using Microsoft Excel. Intraclass correlation coefficients (ICC) were calculated for ToL, SARC, ANT, anxiety, HR, SBP and DBP (GB STAT for MS Windows, Version 7.0, Silver Springs, MD).

Chapter 4

Results

4.0 RESULTS

4.1 RELIABILITY

The reliability as assessed by intraclass correlation coefficients (ICC) was 0.99, 0.97, 0.99, 0.96, 0.97, and 0.97 and for the ToL, SARC, anxiety, HR, SBP, and DBP respectively.

4.2 TOWER OF LONDON (ToL)

The inverted condition showed a significant ($p<0.0001$) 26.9% and 11.7% lower number of correct responses in comparison to the pre- and post-inversion (upright) conditions (Figure 1) respectively. Time to completion was 63.4% and 40.7% significantly ($p=0.027$) slower for the inverted versus

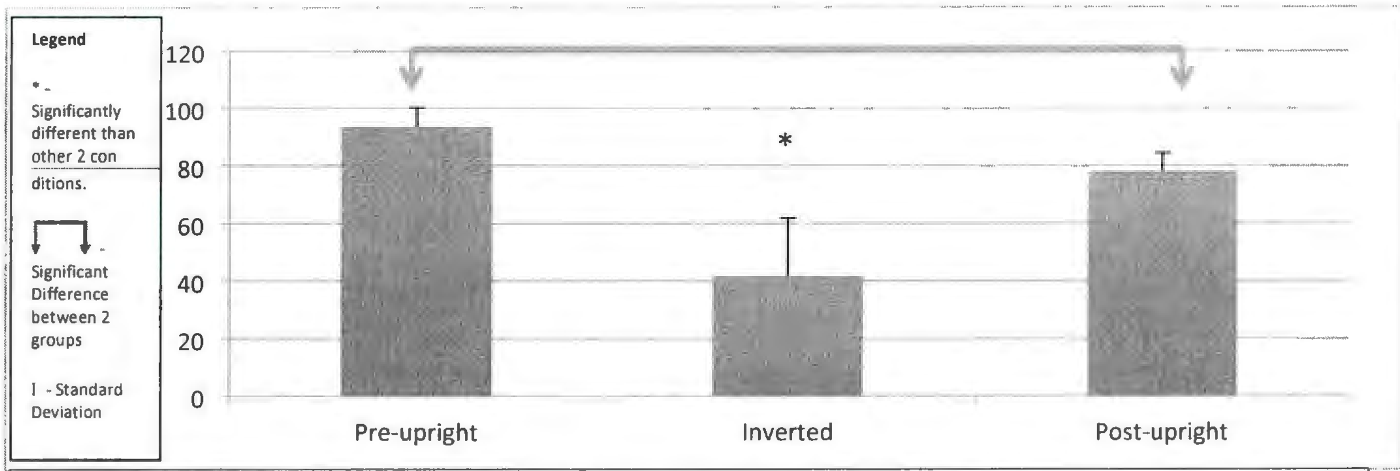

Figure 4.1: Mean Scores for the Tower of London

the pre and post-inversion (upright) conditions (Figure 4.2a and 4.2b).

Significant (p<.01) differences were observed between the pre-upright group and the inversion group as well as in the inversion group and the post-upright group.

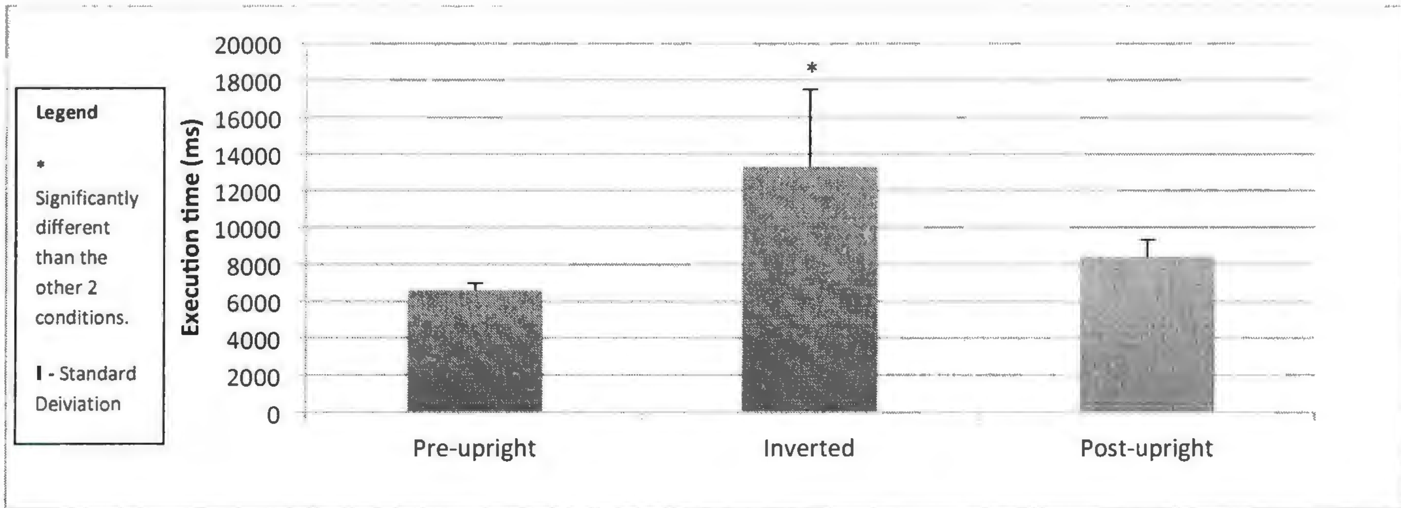

Figure 4.2a: Mean Execution time for Tower of London

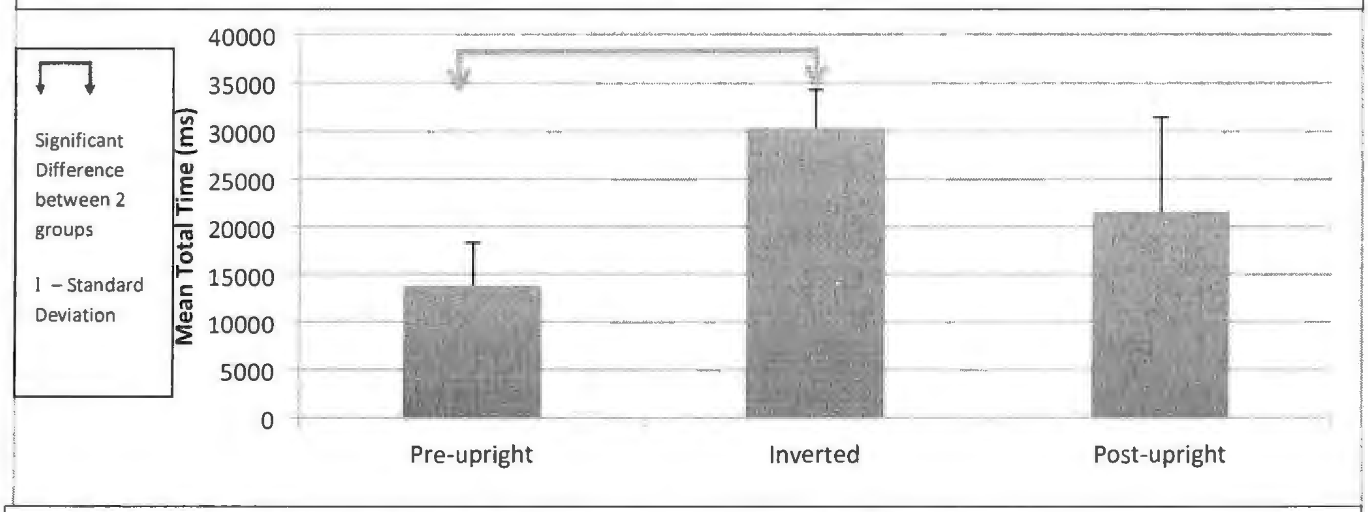

Figure 4.2b: Mean Total Time to Completion for Tower of London

There was a main effect for position with SBP and DBP during the ToL test. SBP was 11.9% and 13.1% lower ($p<0.0001$) with inversion compared to pre- and post-inversion (upright) conditions respectively (Figure 3). Similarly, DBP was 22.2% and 21.7% lower ($p=0.0003$) with inversion compared to pre- and post-inversion (upright) conditions (Figure 4) respectively.

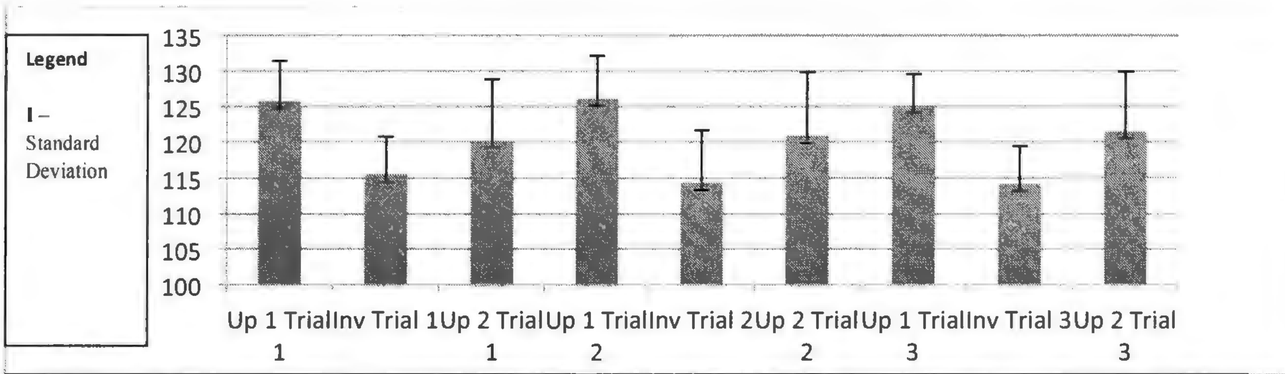

Figure 4.3: Tower of London Systolic Blood Pressure

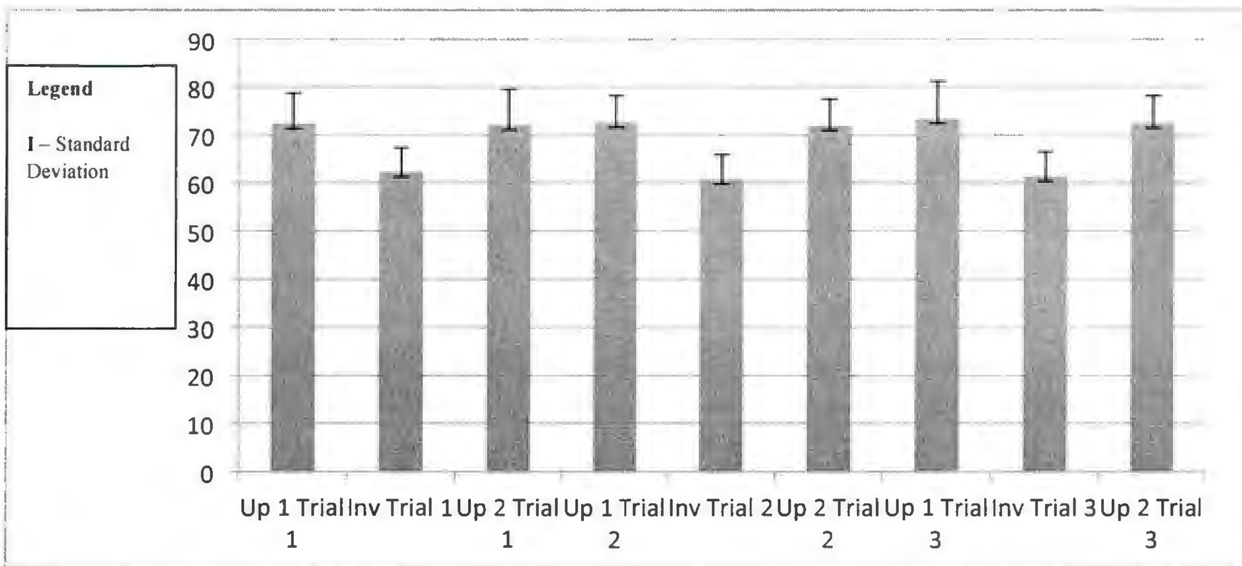

Figure 4.4: Tower of London Diastolic Blood Pressure

There was also a main effect (p<0.001) for position with HR during the ToL test. HR was 10.1% and 10.7% lower during inversion compared to pre- and post-inversion (upright) conditions

4.3 SELECTIVE ATTENTION AND RESPONSE COMPETITION (SARC)

The inverted condition showed a significant (p<0.0001) 8.2% and 4.6% lower number of correct responses in comparison to the pre- and post-inversion (upright) conditions (Figure 4.5) respectively. Reaction time was 10.4% and 11.7% significantly (p=0.027) slower for the inverted versus the pre- and post-inversion (upright) conditions (Figure 4.6) respectively.

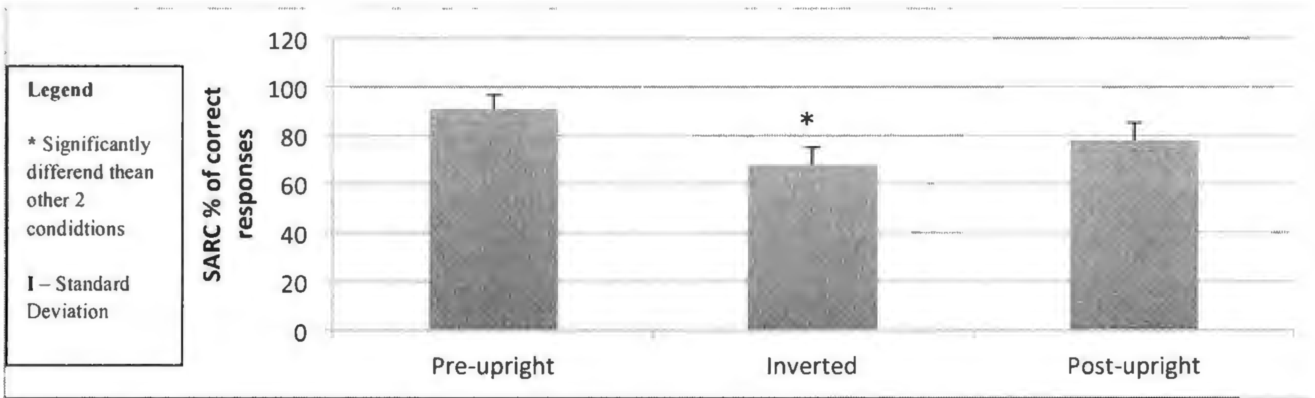

Figure 4.5: SARC, percentage of correct responses

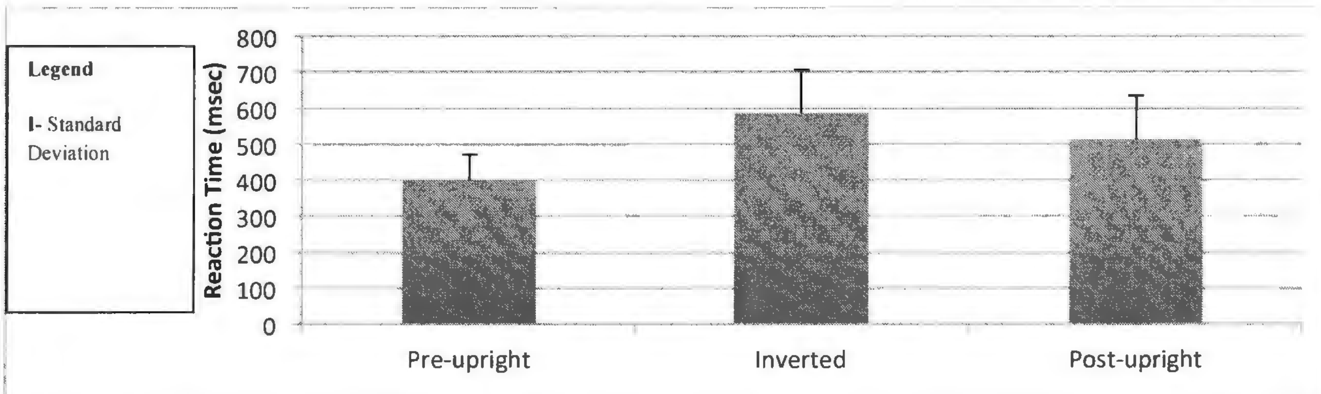

Figure 4.6: SARC, reaction time Means and Standard deviations.

There was a main effect for position with SBP and DBP during the SARC test. SBP was 9.5% and 5.4% lower (p<0.01) with inversion compared to pre- and post-inversion (upright) conditions (Figure 4.7) respectively. DBP was 18.5% and 17.9% lower (p=0.0007) with inversion compared to pre- and post-inversion (upright) conditions (Figure 4.8) resepectively.

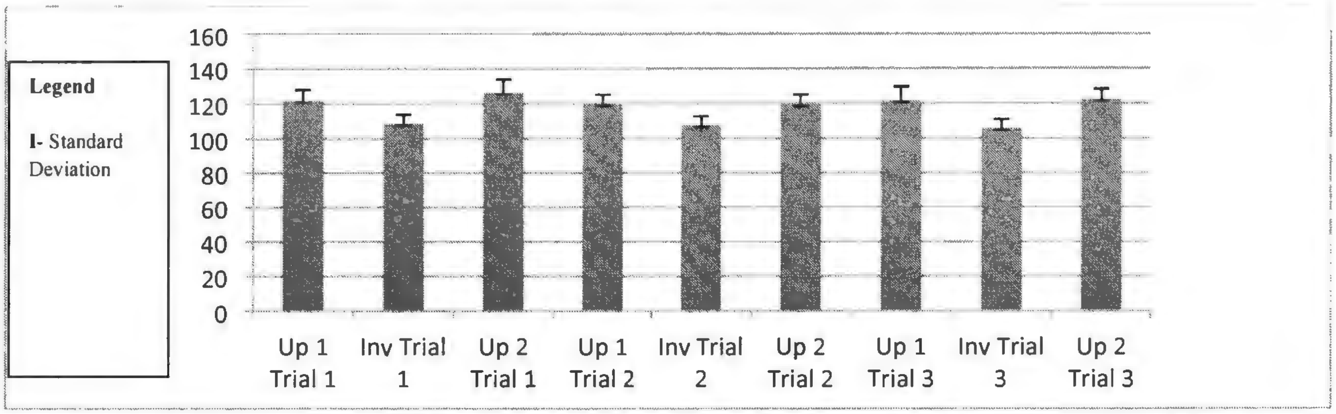

Figure 4.7: SARC experiment SBP Means and Standard Deviations

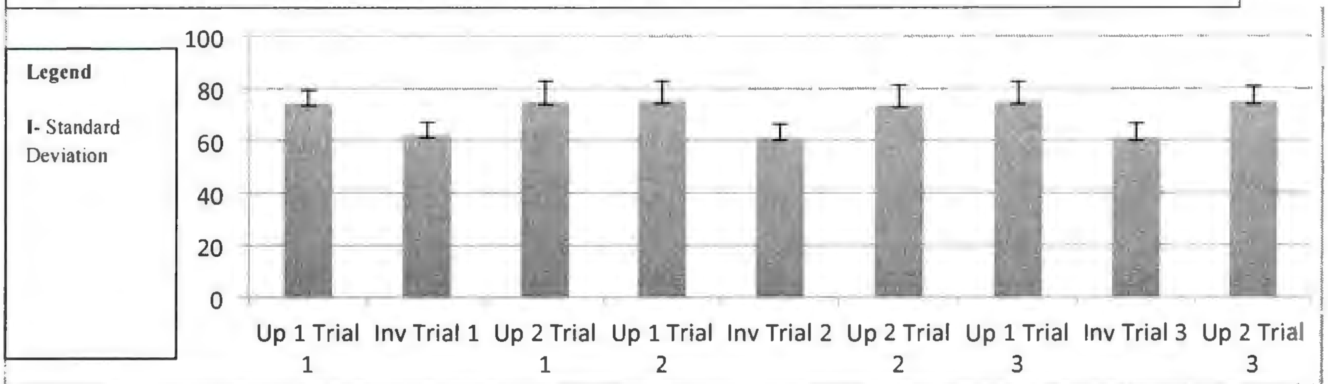

Figure 4.8: SARC experiment DBP Means and Standard Deviations

A main effect ($p<0.001$) for position was revealed for HR during the SARC test. HR was 9.6% and 10.6% lower during inversion compared to pre- and post-inversion (upright), respectively.

4.4 ATTENTION NETWORK TEST (ANT)

A position main effect ($p<0.001$) with HR was apparent during the ANT test. HR was 10.8% and 11.1% lower during inversion compared to pre- and post-inversion (upright) conditions (Figure 4.9) respectively.

No significant differences ($p<0.537$) were observed in the inverted behaviors of alerting, orienting and executive function. The ANT assessment indicated a trend in decreased efficiency with respect to the alerting and orientation cues. No changes were observed with respect to the executive function.

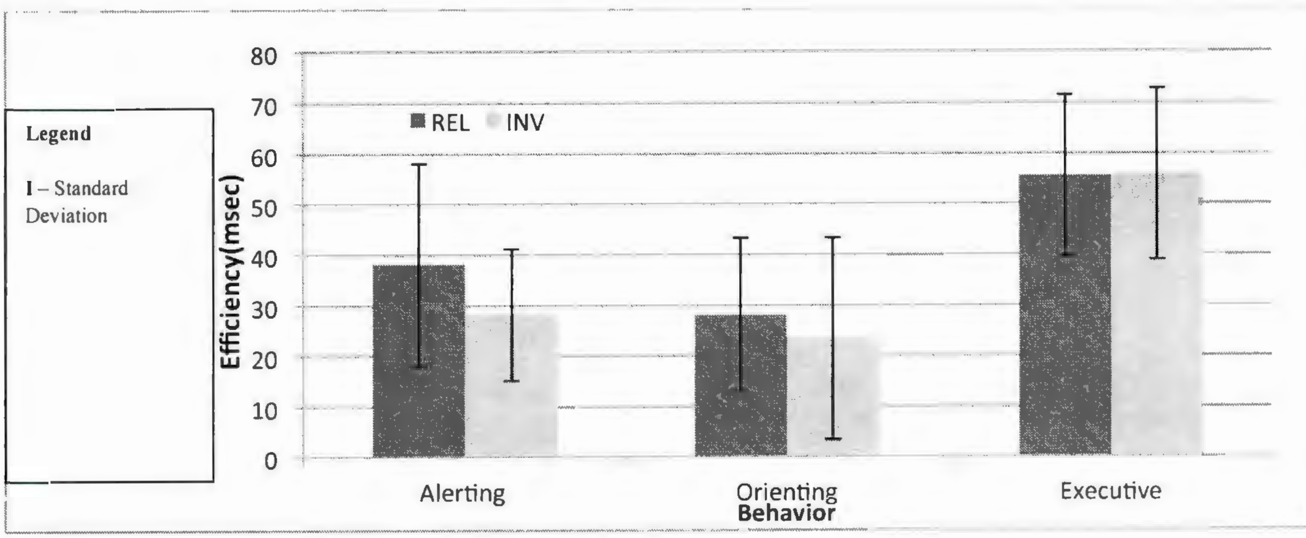

Figure 4.9: Efficiency of ANT behavioural effects

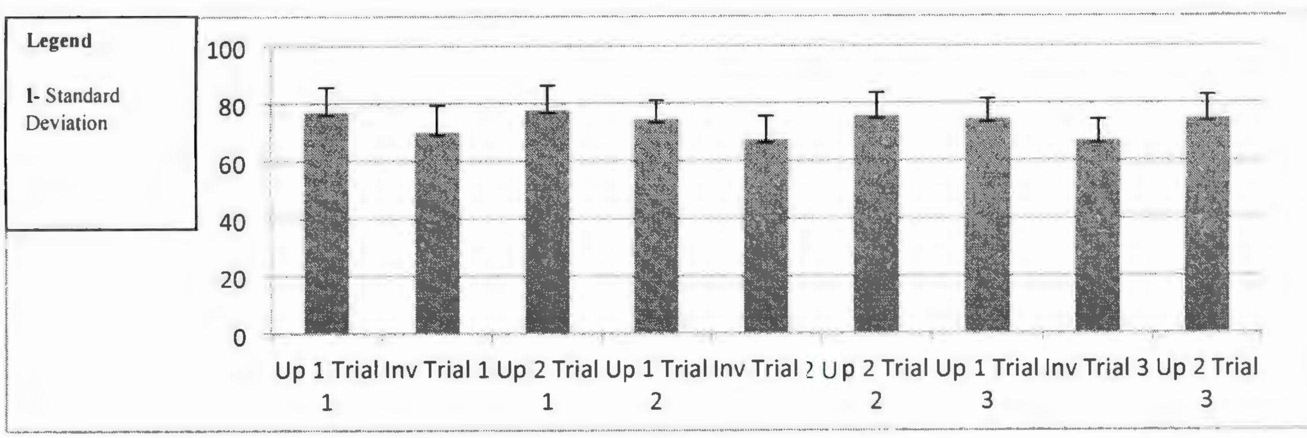

Figure 4.10: Heart Rate Means and Standard Deviations

4.5 ANXIETY

There was a main effect ($p<0.0001$) for anxiety during the experiments. During the inverted condition participants reported a feeling of anxiety 25% higher than the pre-inversion condition and 51% higher than the post-inversion condition (Figure 10).

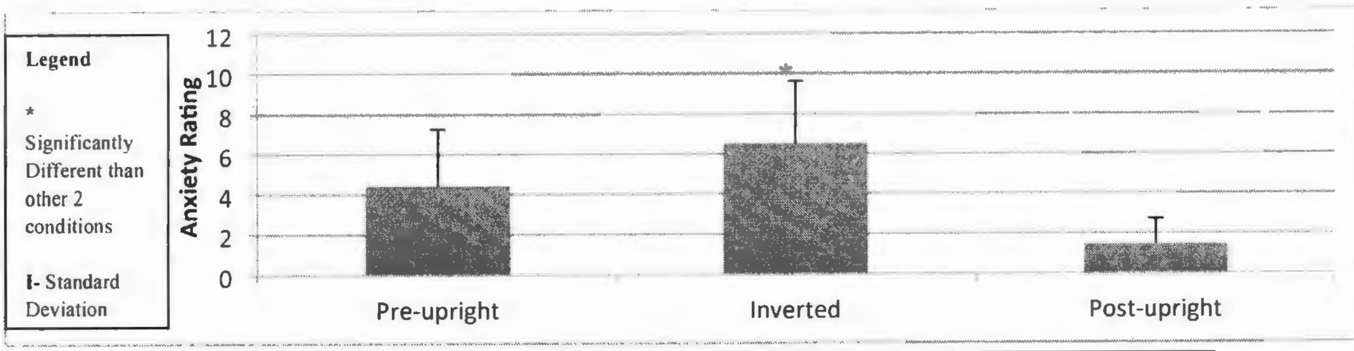

Figure 10: Anxiety Means and Standard Deviation

Chapter 5

5.1 DISCUSSION

The most important findings in the present study were inversion-induced decreased cognition, vigilance, reaction time, heart rate, blood pressure, and anxiety. This is the first study to examine cognition and vigilant responses to inversion. The only two other published studies investigating inversion demonstrated inversion-induced impairments to muscle force and activation (Paddock & Behm 2009, Hearn et al. 2009). They also found decreased heart rate and blood pressure responses. They used the cardiovascular results as evidence of a sympathetic nervous system inhibition that negatively impacted neuromuscular functioning. It is not known if similar sympathetic inhibition may have contributed to the present findings.

Although there is no research available regarding the effects of the seated inverted condition on cognition and vigilance, there is related literature regarding possible mechanisms using tilt and simulated microgravity environments. The present study showed a decreased mean score on assessment as well as an increase in mean execution time and total time to complete the test in the inverted condition for the ToL. Decreased number of correct responses and reaction tine were recorded in the SARC assessment during the inverted condition. While no significant changes were observed during the ANT test, a trend was detected amongst the alerting and orientation behaviours. The observed inhibition of function during the inverted component of the ToL Test demonstrated a decrease in problem solving ability and executive function. Logan et al. (2003) explained that executive control includes processes involved in synchronizing habits, skills, accurate performance, decision making, and planning. These are skills that require deliberate conscious control. Decreased reaction time and accuracy were evident with inversion as represented by SARC test impairments.

There is no direct research demonstrating the effects of HDT on vigilance. Research assessing the effects of HDT on the physiological function of the brain indicates that there is an increase in blood pooling in the upper body and brain that is suggested to impose facial edema, nasal congestion, making the position uncomfortable. It also disrupts the hemodynamics of the brain compromising tissue integrity and function to affected areas of the brain (Hargens et al., 1983). It has also been suggested that HDT increases intracranial pressure. Research suggests that HDT imposes anxiety, restlessness, a pounding vascular headache, nasal congestion that may force mouth breathing, progressive dyspnea, loss of cooperation, overt hostility, and struggles to regain the upright condition. It is recommended that the normal brain is compacted and compromised during HDT (Diringer, 2008).

Increased blood volume to the cephalic area can affect baroreceptors in the carotid artery. The recorded increase in blood flow in the cephalic region results in increased intracranial pressure due to fluctuations in the hydrostatic pressure gradient. Increased activity of baroreceptors in the arteries has been associated with decreased heart rate, as observed in the present study. The decreases in systolic and diastolic blood pressures observed in this research also could be related to the activation of the baroreceptors. It is suggested that when the baroreceptor reflex is stimulated due to an increase in pressure, the baroreceptors in turn communicate with the central nervous system, with feedback signals sent to the autonomic nervous system to reduce arterial pressure (Cooke, et al., 2003). Pertinent research suggests that this reduction in arterial pressure is the net effect of vasodilation of the veins and arterioles throughout the peripheral nervous system, as well as decreased heart rate and stroke volume contraction intensity.

Paddock & Behm (2009) and Hearn et al. (2009) proposed an inversion-induced decreased sympathetic response based on decreased heart rate and blood pressure responses. Similar cardiovascular responses were confirmed in the present study, which again suggests an attenuation of the sympathetic response. Research exposing humans to HDT has also reported general inhibition of the sympathetic nervous system, resulting from an increase in intracranial arterial pressure. This increase in arterial pressure has been linked to the hydrostatic pressure gradient measured between heart and brain. Therefore, the inhibition of the sympathetic response has been linked to changes in the pulsatility and resistance indices as well as the increase in intracranial arterial pressure (Sing & Stock, 2006). It has been speculated that the reduction of sympathetic tone encompasses the cerebral as well as the peripheral vascular bed. It is proposed that decreased sympathetic activation may decrease the excitation of the entire system, negatively affecting cerebral processing time and neuromuscular response times (Kandel, 2000).

Increased intracracial pressure, increased orbital pressure, as well as decreased vestibulo-ocular, and sympathetic responses could have all contributed to the decreases in cognition scores. Research conducted in patients with cryptococcal meningitis and acquired immunodeficiency disorder provides insight that high intracranial pressure leads to impaired cerebral circulation, loss of visual acuity, impairment of cognitive function and cranial nerve abnormalities (Graybill et at., 2000). Examination of patients exposed to sudden increases in orbital pressure due to trauma generally experience decreased tissue perfusion which leads to loss of visual acuity, decreased color vision, and defects in the visual field. The increase of the angular vestibulo-ocular reflex can be undesirably affected by tilt fluctuating the perception of verticality, positioning of retinal images and control of head movements, all of which can negatively affect vigilance performance (Korinth, 2002).

A strong trend was established for decreased orientation and altering in the ANT. No previous studies implementing the ANT in the inverted condition, HDT, or microgravity were available to support or disprove these findings. It has been suggested that as a limitation to the study more data collection could have made the results more significant.

The present study yielded that anticipation of and actual experience of the inverted condition solicited increased self-reported anxiety in participants. The evoked anxiety demonstrated a decrease in intensity as exposure to the condition increased. Eysenck (1967), suggested that neurotic individuals may experience increased arousal resulting from activation of the limbic system. The Cognitive theory of anxiety suggests most individuals experience a transfer in focus due to anxiety leading to unrelated cognitive processing including personal concerns and worrying. It is proposed that this transfer in focus is associated with poor performance on demanding attention and vigilant tasks (Dolcos & McCarthy, 2006). Eysenck et al. (2007) later advocated that anxiety affects executive function.

The literature recommends that vigilance is facilitated by many areas of the brain (Parasuraman et al., 1987) and many subtypes of vigilance require reinforcement from more specific areas. Vigilance is a crucial factor of human performance in various work and recreational environments. Such tasks naturally involve the complete inversion of the body into an upside down position. This position is also unnaturally achieved in dangerous and unnatural situations. This research has demonstrated the possible effects of inversion on tasks of vigilance

Chapter 6

Summary

A decrease in vigilance was observed in the inverted compared to upright posture. Data collected in the ToL, SARC, and ANT demonstrated decrements in vigilant measures during the inverted posture compared to the upright posture. Decreases in heart rate and blood pressure during the inverted posture agreed with data from previous studies suggesting inhibition of the sympathetic nervous system during the inverted posture.

Several mechanisms are suggested that impair vigilant performance during the inverted condition. Disruption to brain hemodynamics resulting in increased intracranial pressure and the activation of baroreceptors in response to these changes, have been implicated as potential causes of inhibition to the sympathetic response. The suggested increase in intracranial pressure, intraorbital pressure, as well as decreased vestibulo-ocular responses have also been referred to as potential causes for declining vigilant performance. Anxiety and transfer of focus during the prior to and during the inverted condition have also been speculated to cause changes in attention and ability to focus.

This research has demonstrated the effects of the inverted posture on tasks of vigilance. Humans require vigilance in day to day, minute to minute function. Occupational health standards governing positions which require precise vigilant function set policies and regulations to promote optimal conditions for employees to maintain high levels of vigilance. It is difficult however to govern the capacity of vigilance in those subjected to overturned automobiles, aircraft, marine craft and trains. It is important to understand the impacts these inverted environments could impose on individuals trapped within them.

Chapter 7

References

Aiello, I., Rosetti, G., Serra, G., Tugnoli, V., Manca, M. (1983). Static vestibulospinal influences in relation to different body tilts in man. *Experimental Neurology*, 79(1): 18-26.

Anastasopoulos, D., Gianna, C.C., Bronstein, A.M. & Gresty, M.A. (1996). Interaction of linear and angular vestibulo-ocular reflexes of human subjects in response to transiemt motion. *Experimental Brain Research*, 110: 465-472.

Angelaki, D.E., Newlands, S.D., & Dickman, J.D. (2002). Inactivation of semicircular canals cause adaptive increases in otolith-driven tilt responses. *Journal of Neurophysiology*, 89: 1635-1640.

AngelakiD.E., McHenry, M.Q., Dickman, J.D., Newlands, S.D., & Hess, B.J.M. (1999). Short-latency primate vestibule-ocular responses during translation. *Journal of Neurophysiology*, 82: 1651-1654.

Angelaki, D.E., Merfield, D.M., & Hess, B.J.M. (2000). Low-frequency otolith and semicircular canal interactions after canal activation. *Experimental Brain Research*, 132: 539-549.

Antonutto, G., & di Prampero, P.E. (2003). Cardiovascular deconditioning in microgravity: some possible countermeasures. *Journal of Applied Physiology*, 90:283-291.

Aubert, H. (1863). Eine scheinbare bedeutende Drehung von Objecten bei Neigung des Kopfes nach rechts oder links. *Virchows Archiv: an International Journal of Pathology*, 20: 381-393.

Aw, S.T., Haslwanter, T., Hamlngyi, G.M., Burthoys, I.S., Yavor, R.A., & Todd, M.J. (1996). Three-dimensional vector analysis of the human vestibulo-ocular reflex in response to high-acceleration head rotations. I. Responses in normal subjects. *Journal of Neurophysiology*, 76(6): 4009-4020.

Baker, C.H. (1959). Attention to visual displays during a vigilance task: Maintaining the level of vigilance. *British Journal of Psychology*, 50: 30-36.

Bauermeister, M., Werner, H., & Seymour, W. (1964). The effect of body tilt on tactual-kinesthetic perception of verticality. *American journal of Psychology*, 77: 451-456.

Baydur, A., Behrakis, W.A., Zin, M.J., Jaegur, J.M., Weiner, J., & Milic-Emili, J. (1987). Effect of posture on ventilation and breathing pattern room air breathing at rest. *Lung*, 165: 341-351.

Billman, G.E., Schwartz, P.J., Stone, H.L. (1984). The effects of daily exercise on susceptibility to sudden cardiac death. *Circulation*, 69: 1182-1189.

Blaber, A.P., Goswami, N., Bodar, R.L., & Kassam, M.S. (2011). Impairment of cerebral blood flow regulation in astronauts with orthostatic intolerance after flight. *Stroke*, 42:1844-1850.

Bondar, R.L., Stein, F., Kassam, M.S., Dunphy, P.T., Bennett, B.S., & Johnson, K.W. (1994). Cerebral blood flow velocities by transcranial Doppler during parabolic flight. *Journal fo Clinical Pharmacology*, 31: 915-919.

Borg, G.A.V. (1973). Perceived exertion: A note in "history" and methods. *Medicine and Science in Sport and Exercise*, 5: 90-93.

Borst, C., Wieling, W., Van Brederode, j.F.M., Hond, A., De Rijk, L.G.,& Dunning, A.J. (1982) Mechanisms of initial heart rate response to postural change. *American Journal of Physiology*, 243: H676-H681.

Bowman, A.J., Clayton, R.H., Murray, A., Reed, J.W., Subhanm M.M., &Ford, G.A. (1997). Effects of exercise training and yoga on the baroreflex in healthy elderly persons. *European Journal of Clinical Investigation*, 127: 443-449

Brindley, G.S. (1965). How does an animal that is drooped in a non-upright posture know the angle through which it must turn in the air so that its feel point to the ground? *Journal of Physiology*, 180: 20.

Broadbent, D.E. (1971). *Decision and stress.* Academic Press: New York.

Button, D.C. (2003). *The Effects of Noise and Contraction Intensity on Vigilance Performance*. (Master's Thesis) Memorial University of Newfoundland: St. John's, Newfoundland .

Carey, B.J., Panerai, R.B., Potter, J.F. (2003). Effect of aging on dynamic cerebral autoregulation during head up tilt. *Stoke*, 34:1871-1875.

Chan, C.Y.W., & Kearney, R.E. (1982). Influence of static tilt on soleus motoneuron excitability in man. *Neuroscience Letters*, 33(3): 333-338.

Cohen RA. (1993). *The Neuropsychology of Attention*. New York: Plenum Press.

Colier, W.M.N.J., Binkhorst, R.A., Hopman, M.T.E., & Oeseburg, B. (1997). Cerebral and circulatory hemodynamics before vasovagal syncope induced by orthostatic stress. *Clinical Physiology*, 17: 83-94.

Convertino, V.A. (1998). Changes in peak oxygen and plasma volume in fit and unfit subjects following exposure to simulation of microgravity. *Acta Physiology Scandanavia*, 164: 251-257.

Convertino, V.A. (1987). Aerobic fitness, endurance training and orthostatic intolerance. *Exercise Sports Science Review*, 15: 223-259.

Convertino, V.A, Tripp, L.D., Ludwig, D.A., Duff, J., &Chelette, T.L. (1998). Female exposure to high G: chronic adaptations to cardiovascular functions. *Aviation Space Environment Medicine*, 59: 57-62.

Cooke, W.H., & Dowlyn, M.N. (2000). Power spectral analysis imperfectly informs in sympathetic traffic during acute simulated microgravity. *Aviation Space Environment Medicine*, 71:1232-1238.

Cooke, W.H., Reynolds, B.V., Yandl, M.G., Carter, J.R., Tahvanainen, K.U., & Kuusela, T.A. (2002). Effects of exercise training on vardiovagal and sympathetic responses to Valsalva's meneuver. *Medicine & Science in Sports & Exercise*, 34: 928-935.

Cooke, W.H., Pellegrini, G.L., & Kovalenko, O.A. (2003). Dynamic cerebral autoregulation is preserved during acute headdown tilt. *Journal of Applied Physiology*, 95: 1439-1445.

Cox, R.H., Russell, W.D., & Robb, M., (1998). Development of a CSAI-2 short form for assessing competitive state anxiety during and immediately prior to competition. *Journal of Sport Behavior*, 21:31-40.

Cox, R.H., Russell, W.D, & Robb, M. (1999). Comparative concurrent validity of the MRF-L and ARS competitive state anxiety rating scales for volleyball and basketball. *Journal of Sport Behavior*, 22: 1-11.

Crandall, C.G., Johnson, J.M., Convertino, V.A., Raven, P.B., & Engelke, K.A. (1994). Altered thermoregulatory responses after 15 days of head down tilt. *Journal of Applied Physiology*, 77: 1863-1867.

Dai, M., Raphan, T., & Cohen, B. (1991). Spatial orientation of the vestibular system dependence of optokinetic after nystagmus on gravity. *Journal of Neurophysiology*, 66: 1422-1439.

Davies, D.R.& Parasuraman, R. (1981). *The Psychology of Vigilance*. London: Academic Press Inc.

Davies, A., Sant'Ambrogio, F.B., & San'Ambrogio, G. (1980). Control of postural changes in end-expiratory volume (FRC) by airways slowly adapting mechanoreceptors. *Respiratory Physiology*, 41: 211-216.

Davies, D.R.& Tunes, G.S. (1970). *Human Vigilance Performance*. London: Stapes Press.

Davy, K.P., Willis, W.L., & Seals, D.R. (1997). Influence of exercise training on heart rate variability in postmenopausal women with elevated arterial blood pressure. *Clinical Physiology*, 17: 31-40.

Denning, D.W., Armstrong, R.W., Lewis, B.H., & Stevens, D.A. (1991). Elevated cerebrospinal pressure in patients with cryptococcal meningitis and acquired immunodeficiency syndyome. *The American Journal of Medicine*, 91:267-272.

Dolcos, F., & McCarthy, G. (2006). Brain systems mediating cognitive interference by emotional distraction. *Journal of Neuroscience*, 26(7): 2072-2079.

Essandoh, L.K., Houston, D.S., Vanhoutte, P.M.< & Sheppard, J.T. (1986). Differential effects of lower body negative pressure on forearm and calf blood flow. *Journal of Applied Physiology*, 61:994-998.

Eysenck, H.J. (1967). *The biological basis of personality*. New York: Springfield.

Eysenck, M.W., Derakshan, N., Santos, R., & Calvo, M.G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, 7(2): 336-353.

Farkas, G.A., Baer, R.E., Estenne, M. & De Troyer, A. (1988). Mechanical role of expiratory muscles during breathing in upright dogs. *Journal of Applied Physiology*, 64: 1060-1067.

Frankenhaeuser, M., Nordheden, B., Myrsten, A.L., & Post, B. (1971). Psychophysiological reactions to understimulation and overstimulation. *Acta Psychologica*, 35:298-308.

Greenleaf, J.E. (1989). Energy and thermal regulation during bed rest and spaceflight. *Journal of Applied Physiology*, 67: 507-516.

Graybill, J.R., Sobel, J., Saag, M., van Der Horst, C., Powderly, W., Cloud, G., Riser, L., Hamill, R., & Dismukes, W. (2000). Diagnosis and management of increased intracranial pressure in patients with AIDS and cryptococcal meningitis. The NIAID mycoses study group and AIDS cooperative treatment groups. *Clinical Infectious Diseases*, 30(1): 47-54.

Gresty, M.A., Bronstein, A.M. & Barratt, H.J. (1987). Eye movement responses to combined linear and angular head movement. *Experimental Brain Research*, 65: 377-384.

Gultekin, E., Ciftci, Z., Develioglu, O.N., Celik, O., Yener, M., Kulekci, M. (2011). Endoscopic orbital decompression of an isolated medial orbital wall fracture: A case report. *ENT-Ear & Throat Journal*, 90(12):E32-E35.

Hanson, A.R., Slane, P.R., Rueckert, P.A. & Clark, S.V. (1995). Squatting revisited: companion of hemodynamic responses in normal individuals and heart transplant recipients. *Brain and Heart Journal*, 74: 154-158.

Hargens, A.R., Tipton, C.M., Gollnick, P.D., Mubarak, S.J., Tucker, B.J., & Akeson, W.H. (1983). Fluid shifts and muscle function in humans during acute simulated weightlessness. *Journal of Applied Physiology*, 54:1003-1009.

Haustein, W. (1989). Considerations on Listing's Law and the primary position by means of a matrix description of eye position control. *Biological Cybernetics*, 60: 411-420.

Head, H. (1923). The conception of nervous and mental energy. II. Vigilance: A physiological state of the nervous system. *British Journal of Psychology*, 14. 126-147.

Hearn, J., Cahill, F., & Behm, D.G. (2009). An inverted seated posture decreases elbow action force and muscle activation. *European Journal of Applied Physiology*, 106: 139-147.

Hebb, D.O. (1955). Drives and the CNS (conceptual nervous system). *Psychological Review*, 62: 243-254.

Hoshi, Y., & Tamura, M. (1993). Detection of dynamic changes in cerebral oxygenation coupled to neuronal function during mental work in man. *Neuroscience Letters*, 150: 5-8.

Iellamo, F., Legramante, J.M., Massaro, M., Raimondi, G., Galante, A. (2000). Effects of a residential exercise training on baroreflex sensitivity and heart rate variability in patients with coronary artery disease. A randomized, controlled study. *Circulation* , 102: 2588-2592.

Jacobsen, T.N., Nielsen, H.V., KAssis, E., & Amtorp, O. (1992). Subcutaneous and skeletal muscle vascular response in human limbs to lower body negative pressure. *Acta Physiology Scandanavia, 144: 247-252.*

Kahneman, D. (1973). *Attention and effort*. Prentice Hall: Englewood Cliffs, NJ.

Kawai, Y., Okuda, Y., & Ogura, K. (1996). Acute responses of brain oxygenation during postural change in humans. *Proceedings of the Sixth World Congress of Microcirculation*. P.697-791.

Kitano, A., Shoemaker, J.K., Ichinose, M., Wada, H., & Nishiyasu, T. (2005). Comparison of cardiovascular responses between lower body negative pressure and head up tilt. *Journal of Applied Physiology*, 98: 2081-2086.

Knikou, M., & Rymer, W.Z. (2002). Hip angle induced modulation of H relex amplitude, latency, and duration in spinal cord injured humans. *Clinical Neurophysiology*, 113(11):1698-1708.

Koizuka, I., Takeda, N., Sato, S., Kubo, T., Atsunaga, T. (1993). Nystagmus responses in normal subjects during eccentric sinusoidal rotation. *Acta Otolaryngol Supply (Stockholm)*, 1501: 34-37.

Korinth, M.C., Banghard, W., Gilsback, J.M. (2002). Pterional orbital decompression in diseases with acute increase of intraorbital pressure. *Orbit*, 21(4): 271-280.

Kurihara, K., Kikukawa, A, & Kobayashi, A. (2003). Cerebral oxygenation monitor during head up and down tilt using near infrared spatially resolved spectroscopy. *Clinical Physiology and Functional Imaging*, 23: 177-181.

Lee, S.M., Williams, W.J., & Schneider, S.M. (2002). Role of skin blood flow and sweating rate in exercise thermoregulation after bed rest. *Journal of Applied Physiology*, 92: 2026-2034.

LeLoirier, P., Klein, G.J., Krahn, A., Yee, R., Skanes, A., & Shoemaker, K. (2003). Combined head up tilt and lower body negative pressure as an experimental model of orthostatic syncope. *Journal of Cardiovascular Electrophysiology*, 14(9): 920-924.

Lewis, B.S., Lewis, N., Gotsman, M.S. (1980) Effects of standing and squatting on echocardiographic left ventricular function. *European Journal of Cardiology*, 11: 405-412.

Logan, G.(2003). Executive control of thought and action: In search of the wild homunculus. *Current Direction in Psychological Science*, 12: 45-48.

Mackworth, N.H. (1950). Researches on the measurement of human performance. Medical Research Council Special Report: London.

Martens, R., Burton, D., Vealey, R.S., Bump, L.A., & Smith, D. (1990). Development of a brief rating instrument of competitive anxiety: comparisons with Competitive State Anxiety Inventory-2. *Proceedings of the Association of Applied Sport Psychology*. Seattle, WA: Association. (pp.82).

Masden, P., Lyck, F., Pederson, M., Olesen, H.L., Nielsen, H.B., &Secher, N.H. (1995). Brain and muscle oxygen saturation during head up tilt induced central hypovolemia in humans. *Clinical Physiology*, 15: 523-533.

Masden, P., Pott, F., Olesen, S.B., Nielsen, H.B., Burcev, I., & Secher, N.H. (1998). Near infrared spectroscopy determined brain oxygenation during fainting. *Acta Physiologica Scandanavia*, 162: 501- 507.

Megangnoul-Schipper, D.J., Vloet, L.C.M., Colier, W.N.J.M., Hoefangels, W.H.L., Jansen, R.W.M.M. (2000). Cerebral Oxygenation declines in healthy elderly subjects in response to assuming the upright position. *Stroke*, 31: 1615-1620.

Merfeld, D.M., (1995). Modeling the vestibule-ocular reflex of the squirrel monkey during eccentric rotation and roll tilt. *Experimental Brain Research*, 106: 123-134.

Merfeld, D.M., Zupan, L., & Peterka, R.J. (1999). Humans use internal models to estimate gravity and linear accesleration. *Nature*, 398: 615-618.

Miyashita, M., Suzuki-Inatomi, T., & Hirai, N. (2003). Respiratory control during postural changes in anesthetized cats. *Journal of Vestibular Research*, 13: 57-64.

Moray, N. (1967). Where is capacity limited? A survey and a model. *Acta Psychologica,* 27: 84-92.

Navon, D., & Gopher, D. (1979). On the economy of the human information processing system. *Psychological Review*: 86: 214-255.

Norman, D., & Bobrow, D. (1975). On data-limited and resource-limited processing. *Journal of Cognitive Psychology*, 7: 44-60.

Njemanze, P.C. (1992). Critical limits of pressure-flow relation in the human brain. *Stroke*, 23: 1743-1747.

O'Leary, D.D., Shoemaker, K., Edwards, M.R., & Hughson, R. L. (2004). Spontaneous beat-by-beat fluctuations in total peripheral and cerebrovascular resistance in response to tilt. American *Journal of Physiology. Regulatory, Comparative and Integrative Physiology*, 287: R670-R679.

Pacquet, N., Hui-Chen, C.W. (1999). Human soleus H-reflex excitability is decreased by dynamic head-and-body tilts. *Journal of Vestibular Research*, 9(5):379-383.

Paddock, N., &Behm, D.G. (2009). The effect of an inverted body position on lower limb muscle force and activation. *Applier Physiology Nutrition ad Metabolism*, 34: 673-680.

Paggani, M., Montano, N., Porta, A., Malliani, A., Abboud, F.M., Birkett, C., & Somers, V.K. (1997). Relationship between spectral components of cardiovascular variabilities and direct measures of muscle sympathetic nerve activity in humans. *CirculationI, 95: 1411-1448.*

Parasuraman, R., Warm, J.S., & Dember, W.N. (1987). Vigilance: Taxonomy and utility. In L.S. Mark, J.S. Warm, & R.L. Huston (Eds), *Ergonomic and human factors: Recent research*(pp. 11-32). Springer-Verlag: New York.

Rea, R.F., & Wallin, B.G. (1989) Sympathetic nerve activity in arm and leg muscles during lower body negative pressure in humans. *Journal of Applied Physiology*, 70: 1401-1405.

Reiling, M.J., Seals, D.R. (1998). Respiratory sinus arrhythmia and carotid baroreflex control lower body negative pressure in humans. *Clinical Physiology*, 8: 511-519.

Rickards, C.A., & Newman, D.G. (2003). A comparative assessment of two techniques for investigating initial cardiovascular reflexes under acute orthostatic stress. *European Journal of Applied Physiology*, 90: 449-457.

Rosekind, M.R., & Gregory, K.B. (2010). Insomnia risks and costs: health, safety and quality of life. *The American Journal of Managed Care*, 16(8): 617-626.

Seals, D.R., & Chase, P.B. (1989). Influence of physical training on heart rate variability and baroreflex circulatory control. *Journal of Applied Physiology*, 66: 1886-1895.

Sargent, E.W., Paige, G.D. (1991). The primate vestibule-ocular reflex during combined linear and angular head motion. *Experimental Brain Research*, 87: 75-84.

Satake, H., Konishi, T., Kawashima, T., Matsunami, K., Uno, T., Imai, S., Yamada, H., and Hirokawa, C. (1994). Intercranial blood flow measured with single photon emission computer tomography (SPECT) during transient -6^0 head down tilt. *Aviation Space Environment Medicine*, 65: 117-122.

Shannon, D.C., Carley, D.W., Benson, H. (1987) Aging of modulation of heart rate. *American Journal of Physiology*, 253: H874-H877.

Shibasaki, M., Wilson, T.E., Cui, J., Levine, B.D., & Crandall, C.G. (2003). Exercise throughout 6^0 head down tilt bed rest preserves thermoregulatory responses. *Journal of Applied Physiology*, 95: 1817-1823.

Smilth, M.L., Beightol, L.A., Fritsch-Yelle, J.M., Ellenbogen, K.A, Porter, T.R., & Eckberg, D.L. (1996). Valsalva maneuver revisited: a quantitative method yielding insights into human autonomic control. *American Journal of Physiology: Heart Circulation Physiology*, 271: H1240-H1249.

Spina, R.J., Bourey, R.E., Ogawa, T., Ehani, A.A. (1994). Effects of exercise training on alpha-adrenergic responses and baroreflex function in older subjects. *Journal of Gerontology*, 49: B277-B281.

Snyder, L.H., King, W.M. (1992) Effect of viewing distance and location of the axis of head rotation on the monkeys vestibulo-ocular reflex I. Eye movement responses. *Journal of Neurophysiology*, 67: 861-874.

Sprangers, R.L.H., Wesseling, K.H., Imholz, A.L.T., Imholz, B.P.M., Weiling, W. (1991) Initial blood pressure fall on stand up exercise explained in total peripheral resistance. *Journal of Applied Physiology*, 70: 523-530.

Takeda, N., Igarashi, M., Koisuka, I., Chae, S.Y., & Matsunaga, T. (1991) Effects of otolith stimulation in eccentric rotation on the vestibulo-ocular reflex in squirrel monkeys. *Acta Otolayngol Supply (Stockholm)* 481: 27-30.

Takeuchi, Y. (2000). Change ion blood volume in the brain during a simulated aircraft landing task. *Journal of Occupational Health*, 42: 60-65.

Tanaka, H., Davy, K.P., & Seals, D.R. (1999). Cardiopulmonary baroreflex inhibition of sympathetic nerve activity in preserved with age in healthy humans. *Journal of Physiology*, 515: 249-254.

Tanaka, H., Sjoberg, S.H., Paige, G.D. (1996). Cardiac output and blood pressure during active and passive standing. *Clinical Physiology* 16: 157-170.

Telford, L., Seidman, S.H., Paige, G.D.(1998). Canal-otolith interactions in the squirrel monkey vestibule-ocular reflex and the influence of fixation distance. *Experimental Brain Research*, 118: 115-125.

Telford, L., Seidman, S.H., Paige, G.D. (1996). Canal-otolith interactions driving vertical and horizontal eye movements in the squirrel monkey. *Experimental Brain Research*, 109: 407-418.

Triesman A. (1964). Verbal cues, language and meaning in attention. *American Journal of Psychology* 77: 206-214.

Trimble, M.H., & Enoka, R.M. (1991). Mechanisms underlying the training effects associated with neuromuscular electrical stimulation. *Physical Therapy*, 71: 273-280.

Tweed, D., Cadera, W., & Vilis, T. (1990). Computing three dimensional eye position quaternions and eye velocity from search coil signals. *Vision Research*, 30: 97-110.

Ueno, L.M. Moritani, T. (2003). Effects of long term exercise training on cardiac autonomic nervous activities and baroreflex sensitivity. *Journal of Applied Physiology,* 89: 109-114.

Virre, E., Tweed, D., Milner, K., & Villis, T. (1986). A reexamination of the gain of the vestibule-ocular reflex. *Journal of Neurophysiology*, 56: 439-450.

Vissing, S.F., Scherrer, U., & Victor, R.G. (1989). Relation between sympathetic outflow and vascular resistance in the calf perturbations in central venous pressure. Evidence for cardiopulmonsry afferent regulation of calf vascular resistance in humans. *Circulation Research*, 65: 1710-1717.

Vroman, N.B., Healy, J.A., Kertzer, R. (1988). Cardiovascular response to lower body negative pressure (LBNP) following endurance training. *Aviation Space Environment Medicine*, 59: 330-334.

Wearne, S., Raphan, T., Cohen, B. (1999). Effects of tilt of the gravito-inertial acceleration vector on the angular vestibo-ocular reflex during centrifugation. *Journal of Neurophysiology*, 81: 2175-2190.

Yakushin, S.B., Raphan, T., & Cohen, B. (2000). Context-specific adaptation of the vertical vestibuolo-ocular reflex with regard to gravity. *Journal of Neurophysiology*, 84: 3067-3071.

Yashukin, S.B., Raphan, T., & Cohen, B. (2003). Gravity-specific adaptation of the angular vestibule-ocular reflex dependence on head orientations with regard to gravity. *Journal of Neurophysiology*, 89: 571-586.

Yerkes, R.M., & DodsonJ.D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and psychology*, 18: 459-482.

Yoshizaki, Yoshida, A., Hayashi, F., & Fukoda, Y. (1998). The effect of posture change on control of ventilation. *Japanese Journal of Physiology*, 48(4): 267-273.