

The Hog-Tie Position and Positional Asphyxia

Study Objectives

To ascertain as to whether the "Hog-Tie" restraint position results in an increased work of breathing.

Methods

This experimental study was performed in a community hospital pulmonary function laboratory. The study subjects were ten health care workers (9 men and 1 woman, age 28 to 59). Individuals that had a large body mass were included in the study (Body Mass Index 28.7 to 49.2 kg/m²). The study subjects were placed into two different positions: 1.) seated comfortably in a chair or 2.) placed into the Hog-Tie prone position with arms handcuffed behind their backs and ankles drawn up with a tie towards the handcuffs. Using the Medgraphics Exercise System measurements of oxygen consumption, carbon dioxide production, oximeter oxygen saturation, tidal volume, respiratory rate and minute ventilation were obtained for each individual in each position at the end of five minutes.

Results

There was a significant increase in the work of breathing for individuals placed into the Hog-Tie position as compared to the seated position as measured by a 23% mean increase in oxygen consumption. Also noted was a 25% mean increase in carbon dioxide production, 44% increase in respiratory rate and 29% mean increase in minute ventilation. There was a 2% mean decrease in oximeter oxygen saturation and not statistically significant 7% mean decrease in tidal volume.

Conclusion

In this study population of health care workers there was an increased work of breathing as measured by oxygen consumption when these subjects were placed into the Hog-Tie position as compared to sitting in a chair. Also noted were increased carbon dioxide production, respiratory rate and minute ventilation and decreased oxygen saturation and tidal volume. It is recommended that no individuals be placed into the Hog-Tie position and especially if there has been antecedent physical struggle or if they are of large body mass.

Introduction

In police work there is a frequent need to restrain individuals for both the safety of the individual and the police. Combative/violent behavior, intoxicated states, drug delirium, psychotic behavior, or resisting arrest are usual situations requiring restraint. There are a variety of methods and restraints used in these situations to achieve physical control of individuals. Some methods of restraint have produced significant morbidity and even mortality for the restrained person.

The "hog-tied" prone position is a commonly employed method of restraint to incapacitate a suspect and transport the suspect. The suspect is placed on the abdomen with hands handcuffed behind the back and ankles secured with a tie and connected to the handcuffs. However, there have been reports of in-custody deaths of individuals restrained in the "hog-tied" position following an episode of vigorous physical combat. Many of those individuals have been obese with "big bellies" and the cause of death has been ascribed to positional asphyxia.

This study investigated some physiologic consequences involved when individuals are placed into the Hog-Tie position. Physiologic mechanisms are considered to explain the field observations of in-custody deaths while in the Hog-Tie position following vigorous combat.

Materials and Methods

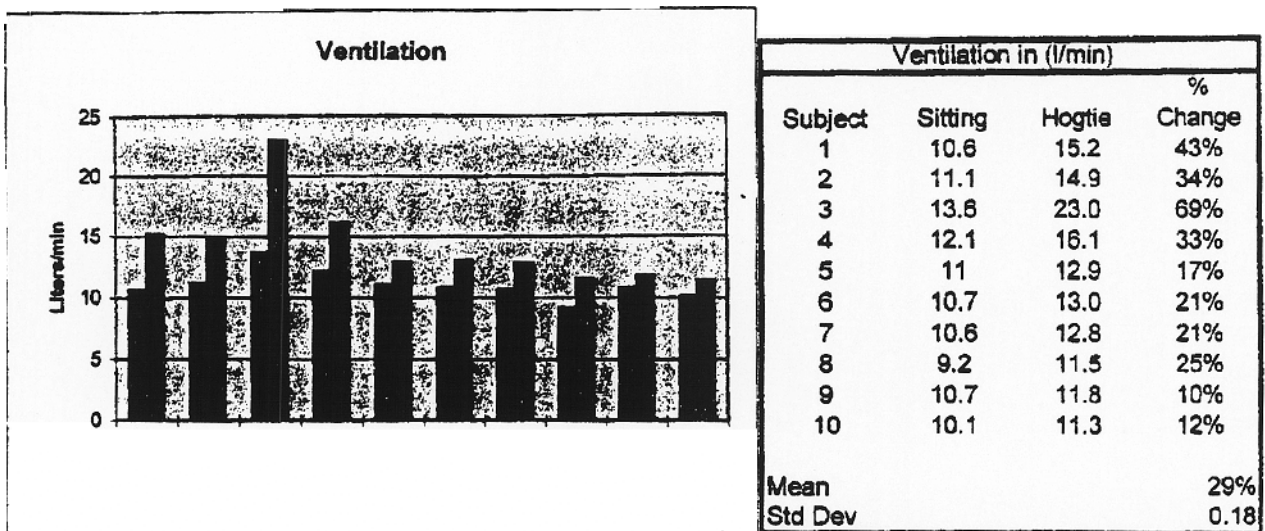
Ten health care workers, 9 men and 1 woman, volunteered to participate in an experimental study. Informed consent was obtained from all individuals and the subjects were financially compensated. None of the individuals had active medical problems and were not taking prescribed medications. Individuals with large body mass were included.

Study subjects were first seated in a comfortable chair with a nose clip applied and the mouthpiece of the Medgraphics Exercise System placed to measure expired oxygen concentration, carbon dioxide concentration, respiratory rate, tidal volume, minute ventilation, heart rate and an oximeter to measure oxygen saturation. Continuous measurements were obtained and, after 5 minutes, when equilibration was assured, final measurements were taken of each parameter.

After a ten-minute rest period, the study subjects were next placed into the prone Hog-Tie position on a padded mat on the floor. Police handcuffs were applied to the wrists behind the back and a tie about the ankles was drawn up towards the handcuffs. A nose clip was applied and the Medgraphics Exercise System mouthpiece was placed with the same measurements taken as in the seated position at the end of 5 minutes.

Results

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(For more details and charts included in the original medical study, please contact Safe Restraints, Inc. for the complete report).

Discussion

Positional asphyxia is said to occur when the body position interferes with the act of respiration and leads to respiratory arrest.

The cause of in-custody deaths of individuals placed into the Hog-Tie position following vigorous combat has been a subject of great controversy. Many Coroner-Medical Examiners have ascribed these deaths as being due to cardiac arrhythmias or the effects of drugs and alcohol while others have concluded that positional asphyxia was the cause of death in these situations.

Dr. Donald Reay, a Medical Examiner for Seattle/King County, was one of the first physicians to consider respiratory mechanisms to explain deaths occurring in individuals that had experienced great physical exertion combating police, then being placed into a Hog-Tie prone position and dying in transport. Dr. Reay explained the cause of these deaths as being due to low oxygen levels and physical exhaustion following extreme exertion plus the added effects of hypermetabolic states caused by drugs, alcohol and altered mental states. He studied 10 normal individuals in good health in both the sitting and "hog-tied" positions following modest exercise (on a Nordic Track until heart rate exceeded 120 beats/min). He noted drops in oxygen saturation as measured by an oximeter and prolonged recovery times for the heart rate to return to less than 100 beats/min in individuals placed in the 'hog-tied' position as compared to the resting seated position. He concluded that positional restraint does have measurable physiologic effects and must be considered in ascribing cause of death.

Another investigator, as published in the *Annals of Emergency Medicine*, 30(5) 578-586, Nov. 97. by Theodore C. Chan, et. al., contends that the phenomenon of positional asphyxia in the Hog-Tie position does not exist. They studied 15 healthy (age 18-40), athletic, non-obese, non-smoking, non-drug using individuals with moderate exercise (175 watts on a bicycle ergometer for 4 minutes) then placing them into the Hog-Tie position. They did observe reductions in lung volumes (mean FVC dropping from 5.31 L to 4.60 L, FEV1 from 4.31 to 3.70 L, and MW from 165 L/min to 131 L/min) but did not observe significant oxygen desaturations or elevations in pCO₂ with arterial blood gases or co-oximetry.

Dr. Chan's study is of limited value since study subjects were excluded because of obesity (body masses over 30 kg/m²), poor physical conditioning, smoking, drug or alcohol use, abnormal pulmonary function tests, being over the age of 40, and if they had any other medical problems. Those individuals excluded were precisely the individuals described as being at risk for experiencing positional asphyxia. This study did show that these healthy athletic persons experienced pulmonary restriction. The Hog-Tie position resulted in a mean decrease in FVC of 13.3%, FEV1 of 14.1%. and MVV of 20.7% as compared to the sitting position.

It is generally accepted by pulmonologists that obesity itself creates some degree of pulmonary restriction and this can be made more extreme by the Hog-Tie position as demonstrated by Dr. Chan's study. D.R. Paul, et.al. (6) studied 11 obese subjects (average weight 138.8 kg) in the sitting and supine positions. Change of posture from sitting to supine was associated with 11% increase in oxygen consumption, 35.5% increase in cardiac output, 17.8% decrease in arteriovenous oxygen difference, 31 % increase in mean pulmonary pressure, 44% increase in pulmonary artery wedge pressure, 21.5% increase in peripheral resistance, 6% decrease in heart rate, and 17.7% increase in shunt-venous admixture.

B.D. Johnson, et.al. (8) demonstrated exercise induced diaphragmatic fatigue in healthy humans. Twelve subjects had Bilateral Phrenic Nerve Stimulation (BPNS) before and after maximal exercise and transdiaphragmatic twitch pressures significantly dropped indicating diaphragmatic fatigue.

M.J. Mador, et.al. (12) studied 10 sedentary subjects to 80% of their maximal working capacity until exhaustion. Bilateral Phrenic Nerve Stimulation (BPNS) was performed before and after exercise and there was a significant fall in diaphragmatic twitch pressure indicating diaphragmatic fatigue and it took 60 minutes to recover.

It is this author's opinion that positional asphyxia does occur and is due to an inability of the individual to achieve the work of breathing against an inspiratory load and results in respiratory muscle fatigue and acute respiratory failure. There are many publications in the pulmonary literature about respiratory muscle fatigue and its contribution to respiratory failure. Most of these studies have involved patients in hospital intensive care units that are being supported by mechanical ventilators and decisions need to be made as to whether the patient is strong enough to breathe on his own without the assistance of the ventilator. Studies on the work of breathing, muscle endurance, respiratory rate/tidal volume ratios, and muscular force generation have shed understanding as to whether a patient can successfully breathe on his own. There are guidelines commonly used now to predict success of breathing unassisted without a ventilator. These measurements require minimum thresholds of inspired force, expired volume from a full breath, breathing rate and average breath volume. If individuals do not meet these criteria, they will fail on their own without mechanical assistance. The same situation exists in individuals that have been physically exhausted and placed into the Hog-Tie position, then into a restricted space, and often with loads placed on their chests from several police officers holding them down. They are unable to meet the demands of work of breathing under these conditions and they can experience respiratory failure.

To understand why the Hog-Tie position produces a greater inspiratory load and increases the work of breathing, one has to examine the mechanics of breathing:

With breathing, expansion and contraction of the chest and abdomen occurs on the front part of the body and the back has no significant respiratory movement. The spinal column serves as a pole-like but flexible frame around which the body parts move. Movement of the chest with breathing is dependent on rib motion which serves to increase and decrease the volume inside of the chest, as indicated in Figure 1.

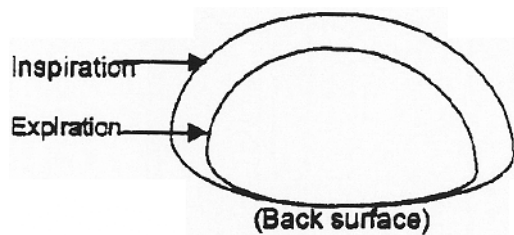


Figure 1. Cross section view ~rough the Chest

The rib motion that allows for expansion of the rib cage from back to front is the "pump handle" action of the ribs. The rib attachment to the vertebral column behaves as an axle and the front end of the rib rises up and down and the back end is secured much as a pump handle would be, and is indicated in Figure 2.

Respiration depends on three critical elements and all three are vital to life.

- 1.) The gas exchange function of the lungs. If the lung itself is diseased or damaged by injury, this results in hypoxemia (low arterial blood oxygen tension.)
- 2.) The patency of the airway. If the airway is obstructed at any level, hypoxemia and hypercapnia (high arterial blood carbon dioxide tension) can result.
- 3.) The muscular pump or bellows that ventilates the lungs. If pump or bellows fails even though the lung may be healthy and the airway patent hypercapnia can result. This includes respiratory failure attributed to physical exhaustion and complicated by adverse body positioning and restriction by space confinement.

The respiratory bellows or pump action depends upon the output drive of the central nervous respiratory center that controls respiratory muscle activity. The respiratory center in the brain stem may not be capable of responding to oxygen demand. Such failure occurs when these respiratory centers are chemically depressed as in drug intoxications: for example, with barbiturates, opiates, or alcohol. In these instances,

the central nervous system drive is attenuated or dampened and fails to respond to biochemical demands of the body. Unless life is artificially supported, death occurs. Since the higher centers of cerebration are also affected by drug intoxication, the intoxicated person may be unaware of impending death. Only careful blood-gas monitoring and artificial support of respiration can overcome the deficits in the central nervous system drive to maintain respiration and life.

Failure of the lung bellows pump function can result from a mechanical abnormality of the thorax that impedes a proper bellows action. Chest injuries or chest deformities can cause bellows malfunction and, ultimately, respiratory failure and death. A poorly functioning or poorly synchronized respiratory bellows may cause severe biochemical disturbances and can require prompt recognition and treatment.

Bellows failure can also occur from respiratory muscular failure. Muscles of respiration may be unable to contract and generate the motion of respiration even though the central nervous system drive is functioning and the thorax is structurally intact. Muscle fatigue is the loss of force subsequent to strenuous muscular exercise and can be the sums of muscle glycogen depletion, lactic acid accumulation, and a decrease in the chemical substrates necessary for muscle contraction.

The respiratory muscles must contract receptively throughout a person's life without failure, and even under conditions of muscle fatigue when there is loss in the capacity to develop force and/or velocity of muscle contraction imposed by loads. Currently, there is no agreed upon standard to measure or diagnose respiratory muscle fatigue despite a great deal of research and investigation.

Summary:

There are ethical and logistical difficulties to laboratory studies of respiratory muscle fatigue and positional asphyxia. It is not possible to re-create the extreme combative conditions and exhaustion that some individuals experience before being placed in the Hog-tie restrained position. This is especially true when the individual may be under the influence of delirium, drugs or alcohol and may have been sustained the weight of multiple police personnel bearing their collective weight on the individual. Study groups of individuals usually consist of healthy volunteers who are not greatly stressed physically and are under no influences of altered mental or metabolic conditions of delirium, drugs or alcohol.

It is my opinion that the field observations and statistics will have to verify that the concept of positional asphyxia is real since the field conditions cannot be ethically reproduced in the laboratory. The same realizations were made in the pediatric medical world with Sudden Infant Death Syndrome (SIDS). Increased SIDS deaths were observed to occur in infants lying in the face down, prone position. Since 1992, the pediatric community has recommended that all infants be placed either in supine or lateral position to reduce the incidence of SIDS (the Back to Sleep Campaign). As the result of the Back to Sleep Campaign, the SIDS death rate has dropped 38% from 1992 to 1996 and the prevalence of the prone sleep position has declined 66% in the same time period. The SIDS realization came about because of field observations and statistics.

In this study we have demonstrated that there is increased work of breathing in health care workers when placed into the Hog-Tie position as compared to sitting comfortably in a chair. There was a 23% mean increase in oxygen consumption. Also noted was a 25% mean increase in carbon dioxide production, 44% increase in respiratory rate and 29% mean increase in minute ventilation. There was a 2% mean decrease in oximeter oxygen saturation and 7% mean decrease in tidal volume.

There is a medical literature that supports the concepts of respiratory muscle fatigue from studies of patients being weaned from mechanical ventilation. Patients that have to breathe against too high of an inspiratory load or expend too much work of breathing will fail to successfully breathe on their own. Likewise, individuals who have become physically exhausted will not tolerate being placed into the Hog-Tie position, especially if they are obese and poorly conditioned. The Hog-Tie position should be avoided and other methods of restraint should be employed.

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