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Brief Reports

EVALUATION OF THE VENTILATORY EFFECTS OF A RESTRAINT CHAIR ON HUMAN SUBJECTS

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☐ **Abstract—Background: Combative individuals often require physical restraint in the prehospital and law enforcement setting. Specialized restraint chairs have been utilized for this purpose in the latter case, but concern has arisen that restrained individuals are at risk for ventilatory compromise and asphyxiation. Objective: We sought to determine if placement in a restraint chair results in alterations of respiratory or ventilatory function. Methods: We conducted a randomized, cross-over, controlled experimental trial in 10 healthy human volunteers performed at a university exercise physiology laboratory. After exercise on a cycle ergometer to 85% of the age-predicted maximal heart rate, subjects were randomized to either a sitting position or restraint chair with arms, legs, and chest secured using standard law enforcement protocol. Subjects remained in each position for 30 min, during which pulmonary function testing of maximal voluntary ventilation (MVV) was performed at 11 and 30 min. Arterial oxygen saturation (O_2sat) and end-tidal PCO_2 levels ($PETCO_2$) were monitored continuously. Subjects repeated the experimental trial in the alternate position after a 45-min rest period. Measures between restraint and sitting positions were compared using a paired *t*-test at each time measurement. Results: There was no evidence of hypoxemia. Mean $PETCO_2$ levels were not statistically different between the two groups at any time ($p > 0.05$), and there was no evidence of hypercapnia. Conclusion: In healthy subjects, placement in a restraint chair resulted in a small decrease in MVV, but did not result in any changes in O_2sat or $PETCO_2$. © 2011 Elsevier Inc.**

☐ **Keywords: restraint chair; ventilation; respiratory; pulmonary**

INTRODUCTION

One of the ways that law enforcement officers control violent suspects while in custody at a detention facility is to utilize a restraint chair. This device offers law enforcement officers an opportunity to restrain a person who is combative and has therefore become a safety issue. Often this includes instances when the violence being engaged in is self-abusing. For example, a suspect intoxicated on drugs repeatedly strikes his head against a wall where even a padded safety cell will not offer full protection against a head injury. The restraint chair is one option for controlling the suspect, and to provide safe maintenance in a position preventing injury, allowing close monitor-

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Figure 1. Restraint chair.

ing, and ensuring safety for law enforcement and medical staff.

The process of restraining an individual in the chair typically involves an already handcuffed suspect placed in the restraint chair, and pushed forward at the waist to limit movements. The ankles are secured to the chair by straps, and then the handcuffs are removed. With several officers holding onto the subject, he or she is leaned back on the chair, and straps are secured across the chest and at the wrists (Figure 1). According to local law enforcement officers, the average time required to restrain a violent person in the bent position in the chair is 30–60 s.

As has occurred with other common uses of force and restraint procedures, there have been reports of sudden deaths of restrained subjects during or after placement in a restraint chair (1–4). Causes of death were postulated to be directly related to the use of the restraint chair, and its inhibiting effect on ventilation, inducing the risk for asphyxiation. Asphyxiation that is caused by body position has been referred to as "positional asphyxia," but typically involves conditions that limit subjects' ability to remove themselves from the ventilatory restricting position, such as extreme alcohol intoxication, trauma (e.g., a car jack slipping), or size (such as an infant stuck between the mattress and crib rail) (5). We were unable to find any studies in the medical literature evaluating the effects of the restraint chair on ventilatory function. This study sought to evaluate the effects of a restraint chair on ventilatory function in human subjects.

METHODS

Study Design

The study was a prospective cross-over, repeated-measures design that compared the respiratory and ventilatory effects over time of the two study positions, restrained in a restraint chair compared to sitting in a regular chair. The study was approved by the University of California, San Diego and the San Diego State University institutional review boards, and all subjects provided informed consent before participating in the study.

Study Setting and Population

Subjects were drawn from a local university campus. Inclusion criteria included subjects who were between 18 and 55 years of age. Before conducting the study, each subject was screened by a physician investigator to insure that there was not present any acute illness that would prevent completion of the study. All women underwent urine pregnancy testing, with a positive test being an exclusion criterion. In addition, subjects having a body mass index (BMI) < 18 kg/m^2 or > 30 kg/m^2 were also excluded from the study. Initial cardiovascular screening was conducted using the Physical Activity Readiness Questionnaire (PAR-Q; http:/www.csep.ca/CMFiles/publications/parq/par-q.pdf). If the subject answered yes to any of the questions on the PAR-Q, they were excluded from the study. Subjects that completed the study received financial compensation for their participation.

Study Protocol

Each subject performed two trials in randomized order, determined after informed consent, approximately 45 min apart during a single visit to the laboratory. The subjects were placed in a seated position and performed a baseline maximal voluntary ventilation (MVV) measurement. This was used for later comparisons with the study positions. Subjects then performed a graded cycling protocol on an electrically braked cycle ergometer (Lode Excaliber Sport, Groningen, The Netherlands) starting at 50 W that increased 15 W/min until reaching 85% of his or her age-predicted maximal heart rate.

Once the target heart rate was achieved, the subject was immediately placed in either the restraint chair or a regular chair without arms, per the randomization. For the regular chair trial, the subject sat in an upright position with feet flat on the floor and the back against the chair. The subjects' hands were placed on the lap.

Table 1. Subject Characteristics

Characteristic	Mean (SD)	Range
Age (years)	24.9 (3.5)	21–31
Weight (kg)	78.0 (17.7)	55.3–111.9
Height (m)	1.72 (0.13)	1.60–1.96
Body mass index (kg/m^2)*	26.0 (2.6)	21.7–29.2

* Range for normal classification is 18.5–24.9.

For the restraint chair trial, the procedure followed standard law enforcement protocol for using the restraint chair. We utilized a chair currently in use by the San Diego County Sheriff's Department, the Pro-straint Chair® (AEDEC International Inc., Beaverton, OR).

The subject was restrained with hands behind the back, and then seated in the restraint chair. The subject was pushed forward at the waist, and the ankles were strapped to the chair. The subject then had the wrist restraints removed, sat back up in the restraint chair, and then was strapped across the chest against the back of the chair. The chest strap was tightened according to the manner in which law enforcement protocol describes, which is tight enough to fit two fingers easily underneath. The arms were then placed down against the side of the chair and the wrists strapped to the chair. Subjects were not allowed to actively struggle against the restraint. Struggle was not allowed as it could not be easily quantified, and it would artificially increase ventilatory minute ventilation and elevate oxygen saturation.

Measurements

Throughout the exercise and restraint portions of the protocol, arterial oxygen saturation (O_2sat) was monitored with a transcutaneous finger pulse oximetry probe, and the electrocardiogram was followed with a three-lead monitor. A facemask that covered the mouth and nose was placed on the subject and the respiratory gas exchange was analyzed breath by breath (Vmax Encore, Cardinal Health, Yorba Linda, CA); it was also used to measure MVV. Heart rate, O_2sat, and end-tidal PCO_2 ($PETCO_2$) were recorded at 0, 1, 5, 10, 20, and 30 min after the subject was initially placed in the chair. The face mask was removed after the 10- and 30-min measurements so that the subject could perform a MVV procedure, which was measured by a licensed respiratory technician. The MVV was measured per American Thoracic Society criteria for reliability and validity.

Outcome Measures

Hypoxemia, as expressed by O_2sat, was defined a priori as $< 94\%$ at the near sea level altitude of San Diego. Hypoventilation, as evidenced by $PETCO_2$, was considered to be > 45 mm Hg, and PCO_2 differences in each measure were evaluated separately to assess any relevant change in the measure.

Data Analysis

Measures between restraint and sitting positions were compared using a paired *t*-test at each time measurement. A p value < 0.05 was considered statistically significant. Clinical significance was determined based on current medical practice. Analyses were performed using SPSS for Windows, version 14.0 (SPSS Inc., Chicago, IL).

RESULTS

All 10 subjects (6 women and 4 men) who were enrolled in the study completed the protocol. No subjects were excluded from participating. Subject characteristics are reported in Table 1. Mean age was 24.9 years, with a mean BMI of 26.0 kg/m^2. Mean MVVs at 11 and 30 min in the restraint chair were slightly lower when compared with the sitting position (167.6 vs. 176.8 L/min, diff = 9.2; confidence interval [CI] 1.9–16.5; and 168.5 vs. 177.4 L/min, diff = 8.9; CI 1.6–16.2, respectively). Comparisons of each position as a percentage of those predicted are presented in Table 2.

Mean O_2sat was not statistically different between the two groups at any time ($p > 0.05$), and there was no evidence of hypoxemia at any time as defined by an O_2sat $< 94\%$. Mean $PETCO_2$ when seated was significantly higher at baseline (36.4 vs. 40.6 %, diff = 4.2; CI 2.2–6.3; $p = 0.001$), but at no other measure (ps > 0.05).

Table 2. Maximal Voluntary Ventilation (% of Predicted) Measures at 11 and 30 Min

	Restraint Chair		Seated			
Measure	Mean	(SD)	Mean	(SD)	Difference (95% CI)	*p* Value
11 min	93.2	(7.5)	98.7	(9.0)	5.5 (1.3,9.7)	0.016
30 min	94.3	(7.0)	98.9	(8.4)	4.6 (1.5,7.7)	0.008

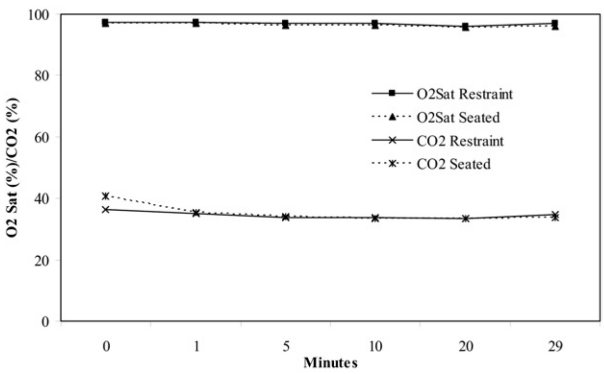

Figure 2. Mean arterial oxygen saturation (O_2sat) and end-tidal PCO_2 ($PETCO_2$) while sitting with or without being restrained. There were little differences in the O_2sat and $PETCO_2$ between trials, thus the values for the restraint trial are superimposed over the seated, control trial.

There was no evidence of hypercapnia as defined by a $PETCO_2 > 45$ mm Hg (Figure 2).

DISCUSSION

In-custody deaths have occurred under many different circumstances and with suspects restrained in various positions. Frequently, asphyxiation has been considered as the cause. Positional asphyxia was a term used for deaths of individuals while restrained in the "hogtie" position. Subsequent physiologic studies have demonstrated that the hogtie position does not impair ventilation and is clinically insignificant and can be considered to be physiologically neutral (6,7).

Although weight is often applied during a field-restraint procedure, it has also been demonstrated that these procedures result in only a small and clinically insignificant decrease of ventilatory function compared to seated measurements. In one study, ventilatory measurements were taken with 50 lbs of weight on the back and there was no evidence of hypoventilation, hypercapnia, or hypoxemia (8). In a related study, there are no clinically significant restrictions of ventilatory reserve when subjects are placed prone with up to 225 lbs of weight on their back (9). Work has not been previously reported with weight on the anterior thorax, as most restraining processes involving police take place with the subject in the prone position. Likewise, when subjects are maximally struggling for 60 s while in a hogtie position, there are no clinically important limitations of metabolic or ventilatory functions (9).

Based on the design of the chair and the way it is used, it seemed that positional asphyxiation was not the cause of the sudden and unexplained deaths of suspects restrained in this chair. However, this remained to be evaluated; thus, the purpose of this study was to assess ventilatory and respiratory function of healthy subjects while restrained in a restraint chair. We did observe a slight decrease in the MVV between the seated and restraint chair positions. This decrease, about 5 L/min or about 5%, though statistically significant, was clinically insignificant, and would not be noticeable to an otherwise healthy subject. There are no differences in the oxygenation or other parameters of ventilation between the two positions. This would suggest that although a small decline was noted in the MVV, there are no clinical respiratory effects on individuals restrained in this chair.

LIMITATIONS

This study was limited by the fact that we did not allow the subjects to struggle against the restraint chair. This is a potential area for further study. We also utilized a small sample size, as this was designed as a pilot study. Larger sample sizes are needed to verify the results. We used techniques as demonstrated by the law enforcement officers, but timing of actual positioning might vary in a field situation. In addition, we used healthy individuals of normal size and who were not under the influence of stimulant or consciousness-altering drugs, including alcohol. Use of these drugs, either alone or in combination, is more typical of field scenarios. Either of these variables may have changed the outcome measures, although there is no physiologic rationale for such a variation to occur.

CONCLUSION

In healthy subjects, placement in a restraint chair results in a small, though clinically insignificant decrease in MVV, but does not result in any changes in O_2sat or $PETCO_2$.

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ARTICLE SUMMARY

1. Why is this topic important?

Patients seen in emergency departments from correctional facilities have sometimes been placed in restraint chairs. It is important for emergency physicians to understand what they are and their impact on ventilatory physiology.

2. What does this study attempt to show?

The ventilatory impact of restraint chairs on human subjects.

3. What are the key findings?

There are no clinically significant changes in ventilatory function from a patient placed into a restraint chair.

4. How is patient care impacted?

Physicians can focus on and treat other causes of sudden patient demise, such as drugs or cardiac etiologies, rather than ventilatory etiologies.