



# National Institute of Justice

R e s e a r c h i n B r i e f

December 2001

## Issues and Findings

**Discussed in this Brief:** The effect of oleoresin capsicum (OC), or pepper spray, on respiration, particularly when combined with positional restraint. Researchers exposed 34 subjects to OC spray, both while sitting and in the prone maximal restraint position.

**Key issues:** OC spray has gained wide acceptance in law enforcement as a swift and effective way to subdue violent and dangerous suspects in the field with relatively little force. As its use has increased, however, OC spray has been associated in the media with the deaths of a number of suspects in custody. Some have argued that OC spray, when used in combination with physical restraints, can lead to significant respiratory compromise, including asphyxiation and death. To test this theory, researchers examined the respiratory effects of inhaling OC spray while in the sitting and restraint positions and compared the results with those obtained in the same two positions when subjects inhaled a placebo spray.

**Key findings:** OC exposure and inhalation do not result in a significant risk for respiratory compromise or asphyxiation, even when combined with positional restraint.

- In the sitting position, OC spray inhalation and exposure resulted in no respiratory compromise.

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## Pepper Spray's Effects on a Suspect's Ability to Breathe

*By Theodore C. Chan, Gary M. Vilke, Jack Clausen, Richard Clark, Paul Schmidt, Thomas Snowden, and Tom Neuman*

Most law enforcement agencies in the United States have authorized the use of oleoresin capsicum (OC), or pepper spray, as a use-of-force option to subdue and control dangerous, combative, or violent subjects in the field. OC, with its ability to temporarily incapacitate subjects, has been credited with decreasing injuries among officers and arrestees by reducing the need for more severe force options.

Despite the success of OC spray, there is growing concern about its safety, particularly when exposure is combined with positional restraint. A number of arrestees exposed to OC, which induces coughing, gagging, and shortness of breath, have died in custody—thus prompting the allegation that OC inhalation places individuals at risk for potentially fatal respiratory compromise.<sup>1</sup>

The National Institute of Justice (NIJ), in conjunction with the Office of Community Oriented Policing Services (COPS), supported a study by medical researchers at the University of California—San Diego to examine the combined effects of OC exposure and positional restraint on respiratory and pulmonary function among 34 volunteer subjects recruited from a law enforcement training academy.

Research findings suggested that inhalation of OC spray does not pose a significant risk to subjects in terms of respiratory and pulmonary function, even when it occurs with positional restraint. However, OC exposure did result in a small but statistically significant increase in blood pressure, the origin of which remains unclear.

### What is OC spray?

Oleoresin capsicum is the oily extract of the cayenne pepper plant. Exposure to OC irritates the skin, eyes, and mucous membranes of the upper respiratory tract. These properties of the pepper plant have been known for centuries. In Japan, samurai warriors threw rice-paper bags filled with pepper extracts at the eyes of their enemies to cause temporary blindness. Chinese soldiers heated red peppers in hot oil to form an irritant smoke to be blown over enemy lines.

In 1973, OC became available as an aerosol spray and was initially used by FBI personnel and U.S. mail carriers to incapacitate humans and animals on a temporary basis. During the late 1980s, it was widely adopted by law enforcement agencies nationwide and was made

Support for this research was provided through a transfer of funds to NIJ from the Office of Community Oriented Policing Services.



## Issues and Findings

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There was no evidence of abnormally low oxygen levels or abnormally high levels of carbon dioxide (CO<sub>2</sub>). In fact, the lower CO<sub>2</sub> levels for this group suggest that OC spray may actually increase ventilation slightly.

- Researchers detected no difference between the OC and placebo groups in the restraint position. There was some decline in pulmonary function, but not enough to be clinically significant. As in the sitting position, OC seemed to increase ventilation.
- OC exposure did, however, result in an increase in blood pressure, perhaps due to the discomfort and pain associated with OC. The clinical implications of this finding remain unknown.
- This study had a number of limitations. First, not all of the conditions that occur when OC and restraint are employed in the field could be reproduced in the laboratory. Second, the effects of prolonged sprays or repeated exposures were not studied. Third, all of the subjects were cadets at the local police academy and were generally healthy. Fourth, the study did not investigate the long-term effects of OC exposure or the potential for complications from chronic occupational exposure to OC.

**Target audience:** Law enforcement policymakers and practitioners, defense and prosecution attorneys involved in OC spray criminal and civil litigation, and medical examiners.

available for use by the general public. Currently, hand-held canister spray models are produced and used in this country. These models produce an aerosol, liquid stream, or foam spray, with OC concentrations ranging from 1 to 10 percent. Pepper sprays are generally regarded as immediately effective, safer, and less toxic than other classic forms of tear gas or mace, such as chloroacetophenone (CN) or *o*-chlorobenzylidene malononitrile (CS).

### About this study

Previous studies have examined the cough-inducing properties of capsaicin (the active ingredient of OC) spray, and a few have looked at the health effects of OC in humans. In addition, some research has been conducted to determine if prone maximal restraint (the “hogtie” or “hobble” position) may lead to positional asphyxia (death caused by obstructed airways or other interference with breathing resulting from body position).

The study discussed in this Research in Brief is the first to investigate whether OC exposure by itself or in combination with positional restraint resulted in respiratory compromise that could put individuals at risk for significant injury or death. The study also examined the effects of OC spray/positional restraint on blood pressure and explored whether the health effects associated with OC exposure might be influenced by—

- Body weight and size.
- Asthma or other pulmonary disease.
- The use of respiratory inhaler medication.
- A history of smoking.

### Study subjects

Thirty-seven individuals (training staff and cadets) from the San Diego Regional

Public Training Institute were recruited and enrolled as subjects for the study. Two subjects were excluded at the outset: One had fractured his ribs and was unable to adequately perform pulmonary function testing; the other had a fractured arm immobilized in a cast, making it impossible to place him in the restraint position. A third subject was excluded after fainting when his blood was drawn in the first trial. He had been exposed to the placebo spray in the sitting position but was never exposed to OC spray or restrained at any time.

Overall, 34 subjects (24 men and 10 women) completed the study. The average age was 31.7 years, with subjects ranging from 22 to 46 years. The average weight was 79.1 kilograms (about 174 pounds), with subjects ranging from 52 to 107 kilograms (approximately 115 to 236 pounds). Seven subjects were classified as overweight (with a body mass index, or BMI, of more than 28 kg/m<sup>2</sup>), and eight subjects had a history of smoking, lung disease, or respiratory inhaler medication use.

### Study design

A randomized, crossover, controlled laboratory study on human subjects was performed, comparing the effects of OC spray and a placebo spray followed by the sitting and restraint positions. The 34 subjects completed 136 separate trials (4 trials per subject) of varying exposure and position such that each served as his or her own control. Eight trials were excluded from analysis because the subject did not adequately inhale when exposed to OC spray. As a result, 128 separate trials were analyzed for the purposes of this study.

For the spirometric and pulmonary function testing data, an additional four trials were excluded from the testing because it did not meet American Thoracic

Society criteria for reproducibility and variability.<sup>2</sup> An additional two trials were excluded from the findings on arterial blood gas data because venous rather than arterial blood was sampled; one trial was excluded from the findings on blood pressure data due to mechanical instrument error.

**Study findings**

**Sitting position.** Researchers found no evidence that OC spray inhalation and exposure resulted in any respiratory compromise in the sitting position. Statistically, there was no significant difference in percent of predicted values for FVC (forced vital capacity—the amount of air that can be expelled from the lungs after a maximal inspiration) or FEV<sub>1</sub> (the amount of air that a subject can forcibly expel in 1 second during a forced expiration test) between the OC and placebo groups at 1.5 and 10 minutes after exposure. Clinically, values remained within the normal range at 1.5 and 10 minutes after OC exposure and inhalation (see exhibits 1 and 2).

OC spray exposure did not result in any statistically significant differences in blood oxygenation when compared with placebo in the sitting position. Blood oxygenation remained at clinically normal levels (see exhibit 3) and carbon dioxide levels decreased after exposure to OC spray. This small but significant finding suggests that ventilation actually increased after OC exposure (see exhibit 4).

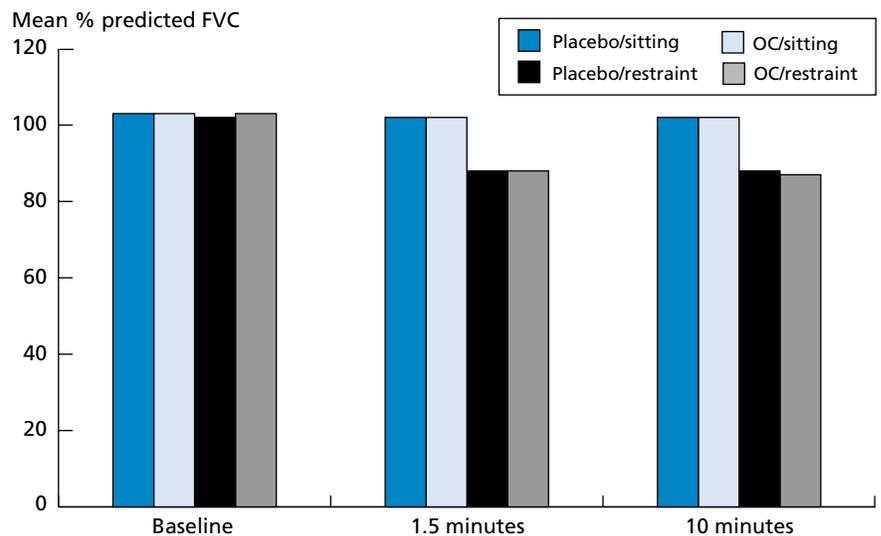
**Restraint position.** The findings of this study concerning the restraint position are consistent with the authors’ previous studies on respiratory function and restraint, which found that restraint led to declines in FVC and FEV<sub>1</sub> but found no evidence of hypox-

emia (low levels of blood oxygenation), hypercapnia (increased carbon dioxide levels), or hypoventilation (decreased ventilation of the lungs).<sup>3</sup>

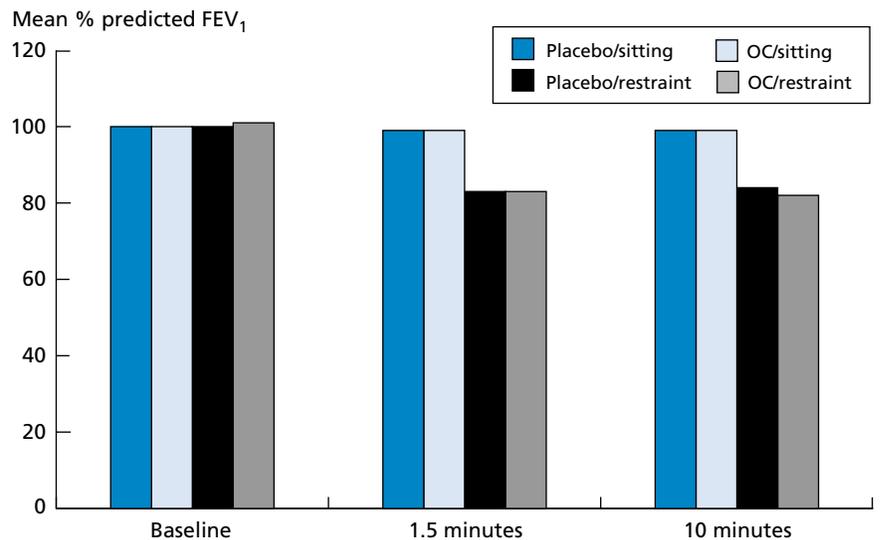
In this study, researchers found no evidence that OC exposure resulted in any additional change in respiratory function in the restraint position.

In both the OC and placebo groups, pulmonary function was restricted in the restraint position, but measurements remained within the normal range. Moreover, there were no statistical differences between the OC and placebo groups relative to these declines (see exhibits 1 and 2).

*Exhibit 1. FVC by exposure and position*



*Exhibit 2. FEV<sub>1</sub> by exposure and position*



Just as in the sitting position, there was no difference in oxygenation in the restraint position between the OC and placebo groups (see exhibit 3). There was also no difference in carbon dioxide levels between the two groups in the restraint position, suggesting that OC exposure had no adverse effect on ventilatory function in restrained subjects (see exhibit 4). Thus, OC inha-

lation had no effect on the pulmonary function changes, oxygenation, or ventilation associated with restraint.

**Cardiovascular effects.** Exposure to OC spray resulted in a small increase in heart rate when compared with placebo. While statistically significant, this difference is probably of no clinical importance, since average heart rates

for all groups (regardless of exposure or position) remained well within normal limits (see exhibit 5).

Mean arterial blood pressure, however, was significantly elevated after exposure to OC spray when compared to placebo in both the sitting and restraint positions. This difference, though small, persisted at 3, 6, and 9 minutes after exposure (see exhibit 6). The reasons for this remain uncertain and may simply be related to the discomfort and pain associated with OC exposure.

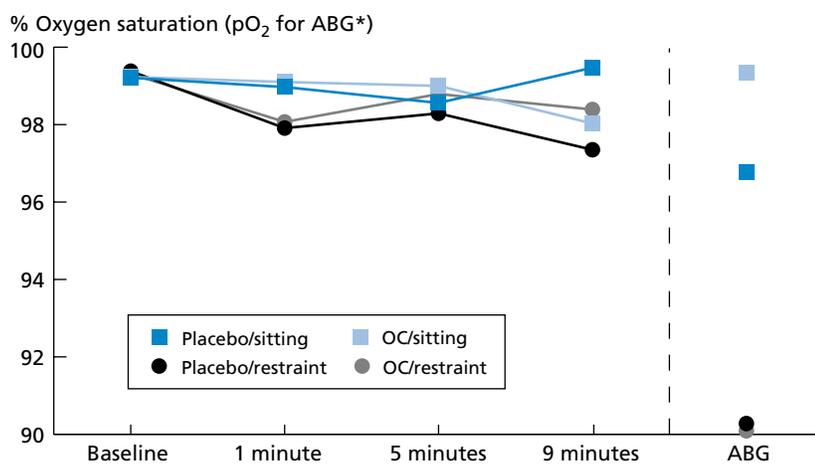
**Effects of body size and weight.**

Researchers found no evidence of additional restrictive pulmonary dysfunction in seven overweight subjects in the sitting or even the restraint position with OC or placebo exposure. In this group, OC exposure did not lead to hypoxemia or hypoventilation in either the sitting or restraint position and actually seemed to improve oxygenation in the sitting position. Clearly, however, these conclusions must be tempered by the small size of this subgroup and the fact that none of the subjects were morbidly obese (BMI greater than 32 kg/m<sup>2</sup>).

**Asthma, smoking, respiratory inhaler medication use.**

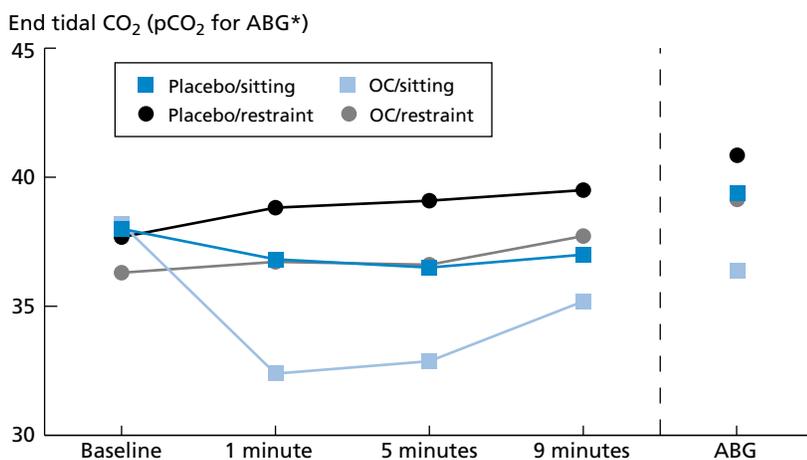
Researchers found no evidence that OC spray inhalation and exposure resulted in respiratory compromise in subjects with a history of lung disease, asthma, smoking, or respiratory inhaler medication use. In this subgroup, OC exposure had no effect on pulmonary function in the sitting or restraint positions. There was also no evidence of hypoxemia, hypercapnia, or hypoventilation after OC inhalation for this group in either the sitting or restraint positions. Yet while these results suggest that OC exposure does not result in respiratory dysfunction in those with potential respiratory

Exhibit 3. Oxygenation by exposure and position



\* Arterial blood gas.

Exhibit 4. Ventilation (CO<sub>2</sub> levels) by exposure and position



\* Arterial blood gas.

abnormalities, it is important to note that this study cannot make definitive conclusions due to the small number of subjects (eight) in this subgroup.

**Study caveats and implications**

**Limitations of this study.** This study was performed on human subjects in a clinical laboratory and did not attempt to replicate all the conditions that may be encountered in the field. Field subjects are often in a state of extreme agitation and “excited delirium” as a result of underlying psychiatric disease or intoxication from recreational drugs. Subjects are often involved in violent physical struggles before, during, and after the use of OC spray or positional restraint. There has been speculation that subjects in the field undergo extreme levels of exertion leading to exhaustion that may affect pulmonary function. Although previous studies have attempted to replicate exertion and struggle, it is unlikely that all conditions that occur in the field—particularly the physiological and psychological effects of stress and trauma—can be reproduced in the laboratory.

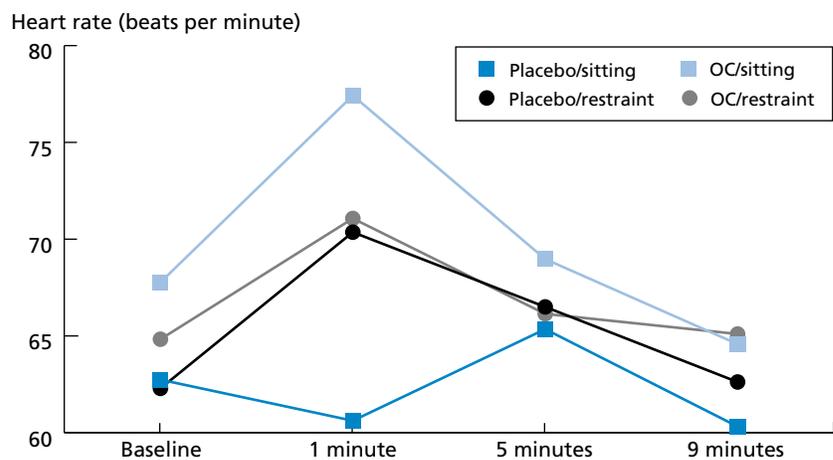
Moreover, as this study focused on inhalation exposure, all subjects wore goggles to reduce OC exposure to the eyes, which causes irritation and pain. Ocular OC exposure may exacerbate the physiological stress of field subjects but was not assessed in this study. In addition, restrained subjects were placed on a medical examination table rather than on a hard surface, as often occurs in field settings.

This study attempted to replicate OC exposure in the field as much as possible in the laboratory setting. In doing so, exact capsaicin dosing was not standardized. Rather, subjects, whose heads were placed in a 5' x 3' x 5' exposure

box, received a standard 1-second spray directed from 5 feet away as dictated by both manufacturer recommendations and local police policies regarding the use of OC. Spraying from less than 5 feet away does not allow for adequate aerosolization of OC and is likely to reduce the amount of inhalation exposure.

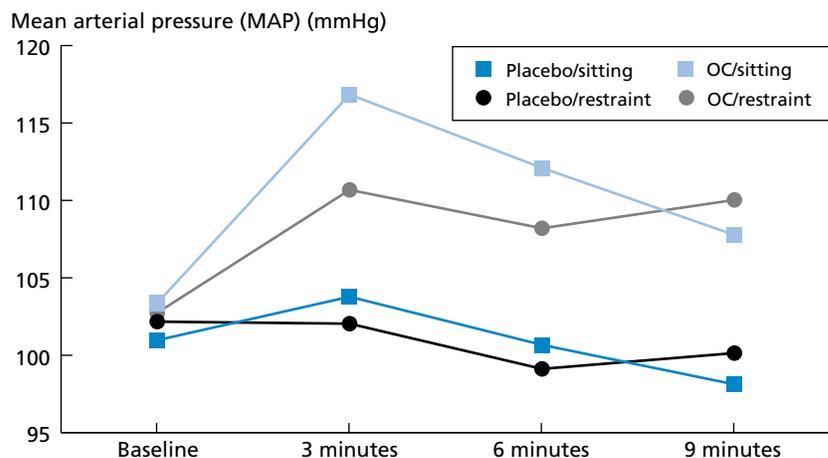
Exposure in the box was limited to 5 seconds while in the laboratory. Although this may seem to be a short period of time, spray in the field usually occurs in an open setting where OC dissipates rapidly. Moreover, by containing the spray within the exposure box, it is likely that subjects were exposed to a much higher

*Exhibit 5. Heart rate by exposure and position*



\* Arterial blood gas

*Exhibit 6. Blood pressure by exposure and position*



\* Arterial blood gas

concentration of capsaicin than might occur in the open air.

This study did not examine repeated OC spray exposures, which commonly occur in the field setting. Researchers used an aerosol form of OC spray, rather than the liquid or foam forms that are also used by law enforcement agencies, because the aerosol form was more likely to be inhaled than other forms and was thus more appropriate for a study on the respiratory effects of OC.

Although subjects were monitored carefully for 1 hour after each trial and were checked by the research staff for significant adverse reactions, they were not assessed for any delayed or long-term effects from exposure. Moreover, this study did not address issues regarding the potential for long-term complications from chronic occupational exposure to OC.

Finally, it is important to emphasize the limited nature of the additional analyses performed on the subgroups of subjects who were overweight or had potential respiratory abnormalities. These groups were small in number and the analysis in this study lacked sufficient statistical power to make any definite conclusive findings.

**Law enforcement implications.** Study findings support the contention that OC spray inhalation, even when combined with positional restraint, poses no significant risk to subjects in terms of respiratory and pulmonary function. Although capsaicin spray has been studied extensively, this study assessed pulmonary and respiratory function after exposure to a commercially available OC spray used by law enforcement agencies nationwide. OC exposure produced no evidence of pulmonary dysfunction, hypoxemia, or hypoventilation

in either the sitting or restraint positions. These findings also applied to the groups of overweight subjects and to those with potential respiratory abnormalities. On the issue of in-custody deaths, this study indicates that OC inhalation and exposure do not cause significant respiratory injury and should not lead to an increased risk of respiratory compromise, arrest, or death—thus lending credence to the large retrospective field studies that

have found little evidence that OC causes significant respiratory injury.

These findings will aid law enforcement agencies by providing data supporting the safety of OC spray, even when used in combination with positional restraint. First, they will provide law enforcement personnel some measure of comfort in the knowledge that they are employing force methods that have been tested and found safe in humans in clinical

## A Glossary of Medical Terms

### **Arterial blood gas (ABG) test:**

A test that analyzes arterial blood for oxygen, carbon dioxide, and pH. It is used to test the effectiveness of respiration.

**Body mass index (BMI):** One's weight (in kilograms) divided by the square of one's height (in meters).

**End-tidal CO<sub>2</sub>:** The partial pressure or maximal concentration of carbon dioxide (CO<sub>2</sub>) at the end of an exhaled breath.

**Forced expiratory volume in 1 second (FEV<sub>1</sub>):** The amount of air that a subject can forcibly expel in 1 second during a forced expiration test.

**Forced vital capacity (FVC):** The amount of air that can be expelled from the lungs after a maximal inspiration.

**Hypercapnia:** The presence of excessive amounts of carbon dioxide in the blood.

**Hypoventilation:** Decreased ventilation of the lungs.

**Hypoxemia:** Deficient oxygenation of the blood.

**Mean arterial blood pressure (MAP):** The average value for arterial blood

pressure (systolic pressure plus diastolic pressure divided by 2).

**Percent of predicted values:** Comparison of a specific person's lung volumes (the amount of air that can be moved in and out with each breath and the amount of air that remains in the lungs) to values that are normal for that person's body size, gender, and ethnicity.

**pO<sub>2</sub>:** The concentration of oxygen in arterial blood.

**Positional asphyxia:** Death caused by obstructed airways or other interference with breathing resulting from body position.

**Prone maximal restraint ("hogtie" or "hobble") position:** A position in which subjects are made to lie prone with wrists and ankles bound together behind the back.

**Pulmonary function test:** Tests designed to gauge how the lungs are carrying out their tasks—of expanding and contracting (when a person inhales and exhales) and of exchanging oxygen and carbon dioxide efficiently between the air (or other gases) within the lungs and the blood.

studies. They may improve the relationship between local agencies and their communities, as the general public will be aware that officers in their communities are employing force methods that have been rigorously studied in a clinical laboratory on human subjects. Questions regarding OC use in cases of custody death will be less likely to contribute to the public controversy and contentiousness that often follow these cases.

Second, this study will aid law enforcement agencies when facing accusations of excessive force based on the unfounded contention that OC exposure results in respiratory compromise. Study data will assist law enforcement agencies in deterring and defending themselves

from litigation that can have a negative impact on the well-being and morale of their agencies, and, more directly, on their personnel and field officers.

Third, on a general public policy level, this study provides solid scientific evidence that can be used in the search for safer methods of restraint. In the past, controversy regarding police force methods and restraint has been based on anecdotal evidence and case reports, rather than the scientific study of human physiology. While many other controversies remain, such as the impact of physiological and psychological stress, external weight compression during restraint, and the cardiovascular effects of stress and restraint, this study provides a physiological and scientific

basis from which to investigate and assess law enforcement force methods and custody restraint procedures.

## Notes

1. Granfield, J., J. Onnen, and C.S. Petty, "Pepper Spray and In-Custody Deaths," Executive Brief: Science and Technology, International Association of Chiefs of Police and National Institute of Justice, March 1994; Bunting, S., "First Death Attributed to OC Occurs in North Carolina," *ASLET Journal* 13 (1993): 13; Steffee, C.H., P.E. Lantz, L.M. Flannagan, R.L. Thompson, and D.R. Jason, "Oleoresin Capsicum (Pepper) Spray and In-Custody Deaths," *American Journal of Forensic Medicine and Pathology* 16 (3) (1995): 185. Flannagan, L.M., *Autopsy Report of the Angelo Robinson Death*, Office of the Chief Medical Examiner, Chapel Hill, NC, 1993: 1:6.
2. American Thoracic Society, "Standardization of Spirometry: 1994 Update," *American Journal of Respiratory and Critical Care Medicine* 152 (September 1995): 1107.
3. Chan, T.C., G.M. Vilke, T. Neuman, and J.L. Clausen, "Restraint Position and Positional Asphyxia," *Annals of Emergency Medicine* 30 (1997): 578.

Findings and conclusions of the research reported here are those of the authors and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

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## For Further Reading

Chan, T.C.; Vilke, G.M.; Clausen, J.; Clark, R.F; Schmidt, P; Snowden, T.; Neuman, T.; "The Effect of Oleoresin Capsicum 'Pepper' Spray Inhalation on Respiratory Function, " in the *Journal of Forensic Science*, 2001, 47(2). In press.

Kaminski, R.J.; Edwards, S.M.; Johnson, J.W. (1999) "Assessing the Incapacitative Effects of Pepper Spray during Resistive Encounters with the Police." *Policing: An International Journal of Police Strategies and Management*, 22 (1):7-29.

Kaminski, R.J.; Edwards, S.M.; Johnson, J.W., (1998) "The Deterrent Effects of Oleoresin Capsicum on Assaults Against police: Testing the Velcro-Effect Hypothesis." *Police Quarterly*, 1(2): 1-20.

An *NIJ Science and Technology Update*, forthcoming 2002, will contain summaries of two NIJ-funded studies of the effects of OC spray: Bowling, J.M., and Gaines, M, "An Evaluation of Oleoresin Capsicum (OC) Use by Law Enforcement Agencies: Impact on Injuries to Officers and Suspects," and Petty, C.S., "Deaths in Police Confrontation When Oleoresin Capsicum Is Used."

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