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Effects of Positional Restraint on Oxygen Saturation and Heart Rate Following Exercise

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This report assesses the effects on peripheral oxygen saturation and heart rate that positional restraint induces when a person is prone, handcuffed, and "hog-tied." Peripheral oxygen saturation and heart rate were monitored at rest, during exercise, and during recovery from exercise for 10 adult subjects. The effects of positional restraint produced a mean recovery time that was significantly prolonged. Consequently, the physiological effects produced by positional restraint should be recognized in deaths where such measures are used.
Key Words: Positional hypoxia—Restraint—Hypoxia.

Investigation of sudden and unexpected death that occurs during the use of physical restraint by the police is a formidable task for forensic pathologists. The use of physical restraint may be preceded by bizarre and violent behavior on the part of the suspect. The risks associated with neckholds have been previously reported (1,2). Another common practice is handcuffing the suspect in a prone position with the hands behind the back. The ankles also may be secured and bound to the handcuffs in a "hog-tied" fashion. Once placed in this position, the suspect may be left unobserved for a period of time. When death occurs, a complex series of events must be evaluated by the investigating pathologist.

Additionally, autopsies in such deaths oftentimes do not identify a specific anatomic abnormality that satisfactorily explains death. When such anatomic findings are lacking, cause of death may be linked to, or associated with, the presence or absence of drugs in the system (3). Other suspected physiological derangements, such as cardiac dysrhythmia or malignant hyperpyrexia (4) or even psychological stress (5), may be identified as an explanation for death. In view of the overall difficulty in assessing such a death, multiple factors need to be evaluated, including the effects of positional restraint. Because the role of positional restraint in such deaths is unclear and may be underestimated, we designed a study to determine if positional restraint has measurable physiological effects.

MATERIALS AND METHODS

Ten normal adults (eight men and two women), all in good health, were studied at rest, during exercise, and during recovery from exercise. The peripheral oxygen saturations and heart rates of the subjects were monitored continuously using an Ohmeda Biox 3700 Pulse Oximeter with ear lobe probe (Fig. 1). Measurements were charted with an Ohmeda 0003 dual channel recorder.

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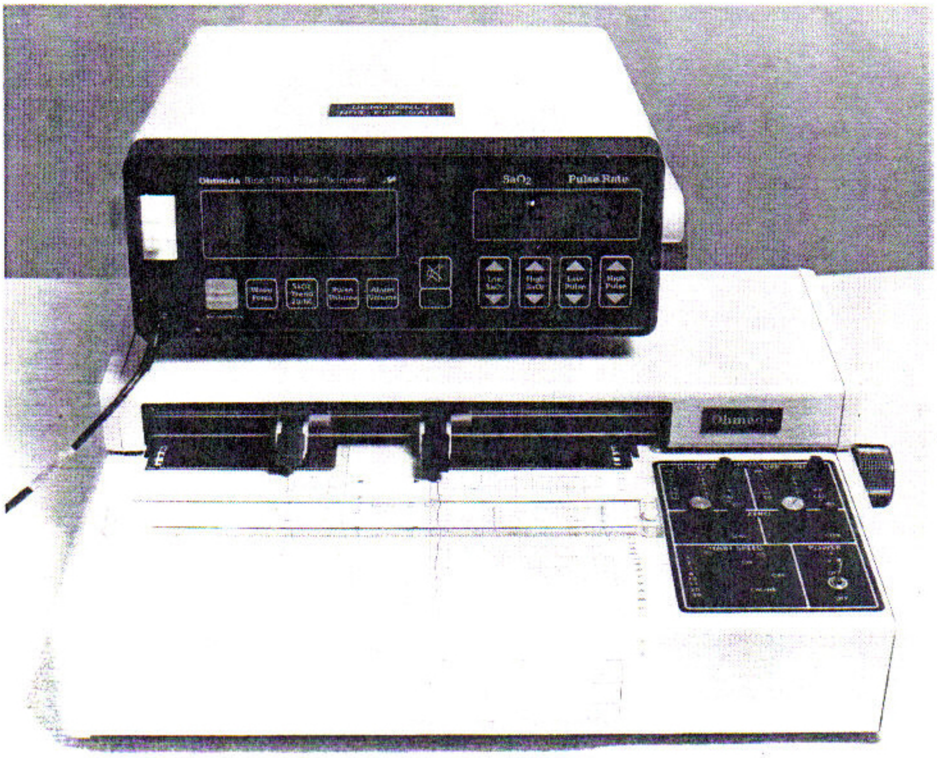

FIG. 1. Pulse Oximeter and recorder used in monitoring test subjects.

Baseline measurements were made with the subject at rest in the sitting position. The subject then exercised using the leg motion part of a stationary exercise cross-country ski machine (Nordic Track). Exercise was continued until the subject's heart rate exceeded 120 beats/min. The subject then dismounted and resumed rest in the sitting position. The mild exercise limit was chosen to assure the safety of the participants. Measurements continued until baseline levels of oxygen saturation and a steady-state heart rate returned (control recovery period).

The sequence was then repeated for each subject with the added factor of positional restraint. After baseline measurements and exercise to a heart rate of greater than 120 beats/min, the subject dismounted, assumed a prone position, and was immediately hand-

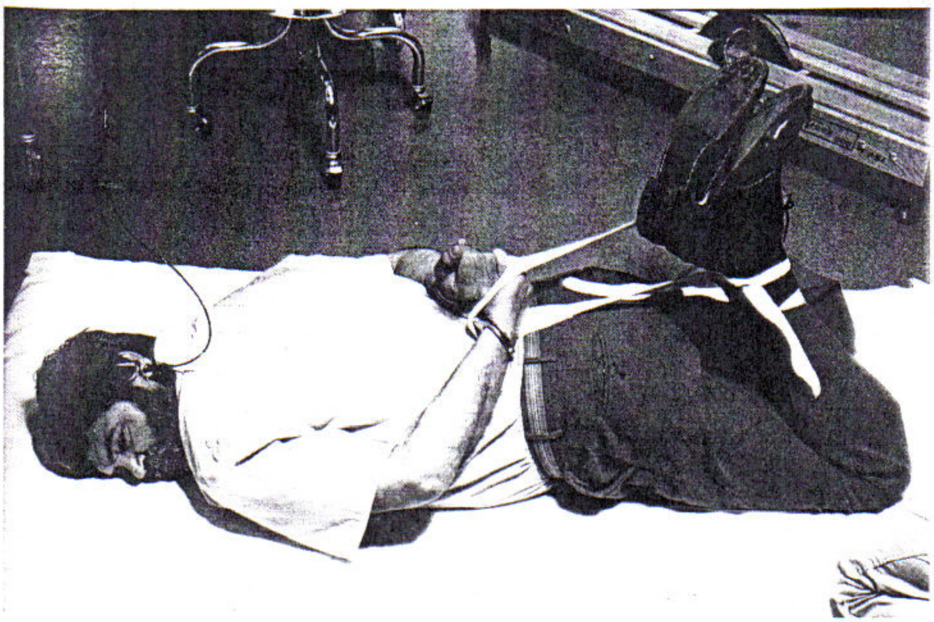

FIG. 2. Restrained position of test subject with handcuffs and tied ankes. The Pulse Oximeter ear lobe probe is attached to the left ear.

TABLE 1. *Oxygen saturation recovery time in minutes*[a]

Subject	Unrestrained	Restrained	% Change
1	.83	1.25	+51
2	1.06	1.25	+18
3	1.01	1.15	+14
4	1.23	1.26	+2
5	1.00	.51	−49
6	.95	1.03	+8
7	1.00	1.13	+13
8	1.13	2.80	+148
9	.23	1.31	+469
10	1.11	1.13	+2
Mean	.95	1.28	+68

[a] Oxygen saturation recovery occurred when oxygen saturation percentage reached baseline levels.

cuffed with hands behind the back. The ankles were bound together with cloth hospital restraints and secured to the handcuffs, placing the subject in a "hog-tied" position (Fig. 2). Measurements were continued until baseline oxygen saturation and a steady-state heart rate returned (test recovery period).

The intervals from cessation of exercise to return of oxygen saturation to baseline levels and return of heart rate to <100 beats/min (end of tachycardia) were measured directly from the charts. The recovery periods were calculated (in minutes) and the means for control and positional restraint conditions compared. The differences of the means were evaluated for statistical significance by *t* test analysis.

RESULTS

The baseline measurements of peripheral oxygen saturation varied from 94 to 100%. Baseline heart rates varied from 52 to 90 beats/min. The drop in peripheral oxygen saturation during exercise and recovery varied to levels of 85–90%. A poor quality heart rate tracing was obtained during recovery for one subject and was excluded from the data.

Data comparing control and test intervals of recovery as determined by oxygen saturation are shown in Table 1. The recovery period was prolonged under conditions of positional restraint in nine of the 10 subjects. The increases varied from 2 to 469% of control intervals. The remaining subject's interval decreased by 49%. The mean time to recovery was 1.28 min during positional restraint and 0.95 min under control conditions, with a mean percentage of increase of 68%. The means were found to be significantly different ($p < .05$).

TABLE 2. *Heart rate recovery time in minutes*[a]

Subject	Unrestrained	Restrained	% Change
1	.53	1.26	+138
2	0.40	1.63	+307
3	0.68	0.70	+3
4	0.18	0.68	+278
5	1.40	1.73	+23
6	.18	0.70	+289
7	0.58	0.73	+25
8	.90	1.10	+22
9	.26	.15	−42
Mean	.56	.96	+116

[a] Heart rate recovery occurred when heart rate returned to <100 beats/min.

Data comparing control and test intervals of recovery as determined by heart rate are shown in Table 2. The recovery period was prolonged under conditions of positional restraint in eight of nine subjects. The increases varied from 3 to 307% of control intervals. The remaining subject's interval decreased by 42%. The mean time to recovery was .96 min during positional restraint and 0.56 min under control conditions, with a mean percentage of increase of 116%. The means were found to be significantly different ($p < .05$).

DISCUSSION

The results show that positional restraint can prolong recovery from exercise as determined by changes in peripheral oxygen saturation and heart rate. The mechanisms by which this occurs are unclear but may include restriction of thoracic respiratory movements, airway compromise, or physical stimulus of catecholamine release during exercise. Physiologic changes of positional restraint occurred in normal subjects exposed to mild exercise. Extreme physical exertion as occurs in a violent struggle could amplify this response. Drug or ethanol intoxication or the presence of demonstrable natural disease might well combine with positional restraint to prolong and amplify this deleterious effect.

This study found positional restraint to have measurable physiologic effects. While the relevance to the study of sudden and unexpected death remains unclear, positional restraint and its effects should be considered when investigating deaths in persons who were handcuffed in the prone position. Additional research is needed to better understand the pathophysiology involved in these deaths. □

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