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The Effect of Physical Restraint on a Violent Patient in the Prone Position on the Quality of Breathing: A Pilot Simulation Study.

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Abstract

OBJECTIVES: Physical restraint in the prone position is still utilized in healthcare facilities to immobilize violent patients. It is associated with the sudden death of violent patients. The aim of this study is to objectify the impact of physical restraint in the prone position on spirometric and ventilatory parameters.
DESIGN: A pilot simulation study.
MATERIAL AND METHODS: Ten university students were included in the study. They underwent two types of physical restraint: in the prone position with "chest kneeling" and in the lateral position. Spirometric parameters (FVC, PEF and FEV1%) and ventilatory parameters ($EtCO_2$ and respiratory rate) were measured before initiation and after five minutes of physical restraint.
RESULTS: Both methods of physical restraint resulted in a decrease in FVC ($p = 0.005$ or $p = 0.047$) and PEF ($p = 0.005$ or $p = 0.028$). No significant changes were observed in $EtCO_2$ and respiratory rate.
CONCLUSION: Physical restraint in the prone position should not be used in healthcare.

Abbreviations:

FVC	- Forced Vital Capacity
PEF	- Peak Expiratory Flow
FEV1%	- Forced Expiratory Volume in 1 second
$EtCO_2$	- End-Tidal Carbon Dioxide
RR	- Respiratory Rate
BMI	- Body Mass Index
CO	- Cardiac Output
HR	- Heart Rate
SpO_2	- Blood Saturation
MVV	- Maximum Voluntary Ventilation

ORIGINAL ARTICLE

INTRODUCTION

Law enforcement officers and healthcare workers employ physical restraint when dealing with individuals who are aggressive, uncooperative or violent (Steinberg, 2021). Manual restraint is part of a spectrum of "restrictive interventions" used for the emergency short-term control of violence and aggression in individuals whose behavior poses a risk of significant or life-threatening harm to themselves or others (Barnett, 2016). The purpose of manual restraint is to safely immobilize the service user. Paramedics often physically restrain a violent patient in pre-hospital emergency care. Patient violence is frequently caused by the influence of drugs or psychiatric illness (Stratton, 2001). We must also mention the factors that we can influence, such as inappropriate communication, frustration, anger, hunger or stress, as direct causes of violence. It also appears that a factor contributing to inappropriate patient behaviour may be the unprofessional behaviour of some pre-hospital emergency personnel (Knor *et al.* 2020). More than 20 years ago, sudden deaths of violent patients after physical restraint in the prone position began to be systematically reported (Stratton, 2001). It is the psychiatric diagnosis, at different ages, that can be a factor in the development of aggressive behaviour that is perceived by health professionals as risky, even threatening (Bartík *et al.* 2022; Vostrý *et al.* 2022).

Current methods of physical restraint include the use of "hogtie restraint," where the subject's wrists are handcuffed behind their back, and their ankles are strapped (hobbled), also known as the prone maximal restraint position. Other physical restraint techniques involve physically limiting the extremities while an individual is placed in a prone position and applying downward pressure on the subject's back while in the prone position. Individuals who succumbed while subjected to these restraint positions meet the previously established criteria for positional asphyxia, and their postmortem diagnosis can be termed as restraint asphyxia (Steinberg, 2021). Often such restrictions are labelled as inhumane by those around us. On the other hand, some paramedics in the Visegrad Group have pepper spray for personal self-defence in critical situations without police presence, but previous research suggests that this tool is not appropriate (Pekara *et al.* 2022). From this point of view, however, it is necessary to remember those countries where the prone position is illegal when restraining a patient (NICE, 2017; Kupas *et al.* 2021).

The impact of physical restraint in the prone position on changes in ventilatory functions has been the subject of several studies. The results of these studies are heterogeneous and burdened by numerous limitations (Meredith, 2005; Parkes, 2008). For this reason, we conducted a study aimed at analyzing changes in spirometric parameters and end-tidal carbon dioxide in ten students who were physically restrained in the prone position with their "chests kneeling" and hands bound behind their backs. The aim of this study is to compare changes in spirometric parameters during patient restraint in the prone and lateral positions.

MATERIAL AND METHODS

This is a pilot simulation study that examined the effects of restraining a violent patient in the prone position on alterations in spirometric parameters. Ten university students, comprising an equal distribution of five males and five females, participated in the pilot study. The experimental investigation took place at the Simulation Center of the Faculty of Health Studies, University Jan Evangelista Purkyně in Ústí nad Labem. The study exclusively enrolled physically healthy participants with a BMI below 35, each of whom submitted a health declaration before participation. Approval for the study was granted by the Ethics Committee of the Faculty

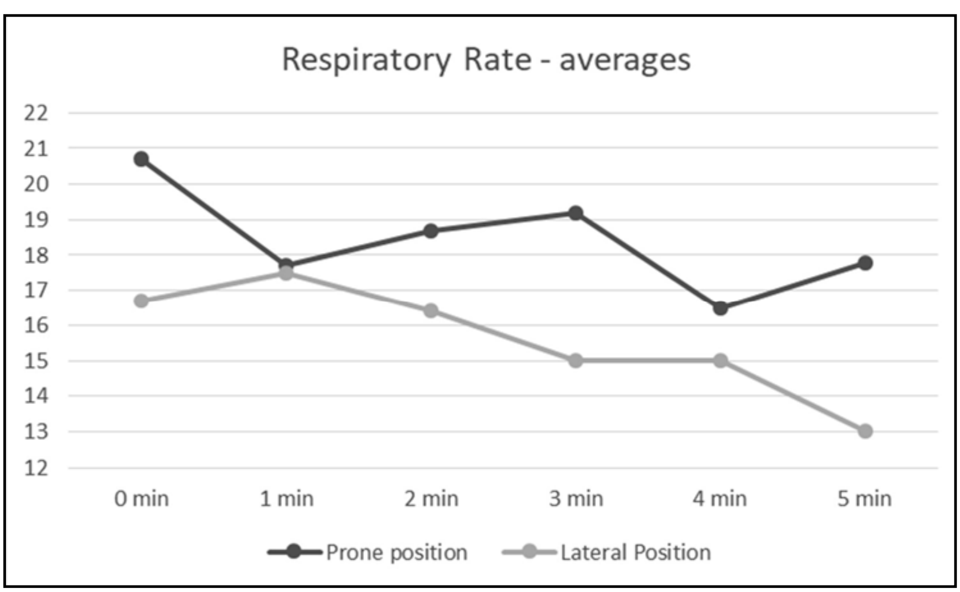

Fig. 1. Respiratory rates during physical restraint in the prone position (kneeling) and in the lateral position

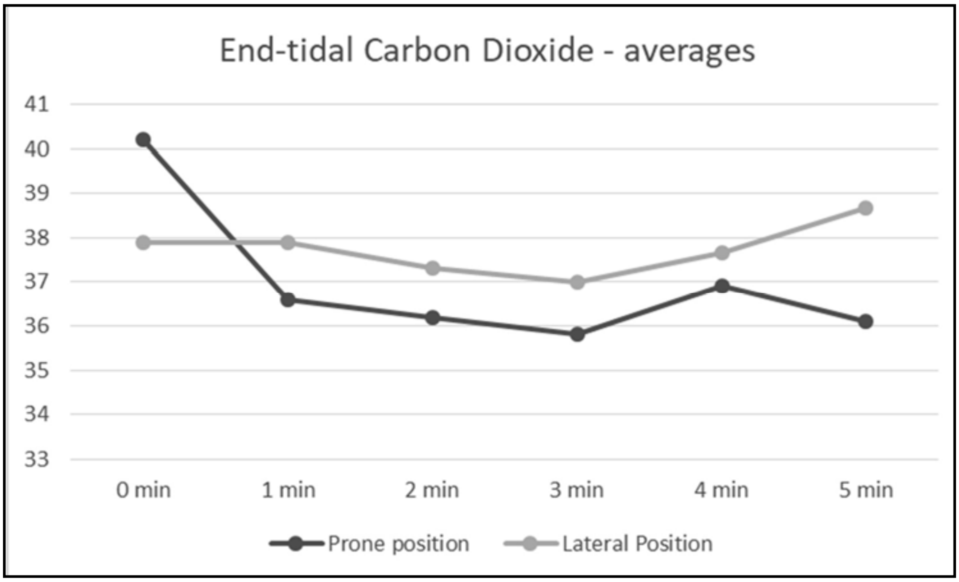

Fig. 2. End-tidal carbon dioxide during physical restraint in the prone position (kneeling) and in the lateral position

of Health Studies at the University Jan Evangelista Purkyně. Participants were provided with relevant information verbally and in writing. Written consent was obtained prior to participation. Every participant experienced a physical constraint that involved kneeling on the chest while in the prone position with hands bound behind their back. The kneeling procedure was administered by a researcher weighing 80 kg. Before positioning the participant in the prone position, spirometric examinations (FVC, FEV1%, and PEF) were conducted in a seated position. Predicted values (%) calculated using spirometry based on age, weight, and height were selected for the analysis. Subsequently, continuous monitoring of end-tidal carbon dioxide, respiratory rate, heart rate, and blood saturation (SpO_2) was initiated. The $EtCO_2$ and RR was measured using a LifePak 15 monitor/defibrillator (Stryker Company, United States). Testing was performed using a Microstream Smart CapnoLine Adult. $EtCO_2$ was monitored during five minutes of physical restraint. Values were recorded every minute. At the end of the fifth minute of kneeling, spirometric examination in the prone position was conducted, blood pressure was measured, and values of $EtCO_2$, respiratory rate (RR), heart rate (HR), and blood saturation (SpO_2) were recorded. After concluding the physical restraint involving kneeling in the prone position, a 60-minute rest period followed, after which a control test was conducted in a lateral position with bound hands. In the lateral position, no pressure was applied to the participant. Identical testing of all parameters was conducted as during the physical restraint in the prone position.

The paired Wilcoxon test was used for the statistical analysis of differences in spirometric parameters (FVC, PEF, and FEV1%) before initiation and after five minutes of physical restraint in both intervention and control groups. The Friedman test was employed to compare six measured values of respiratory rate and $EtCO_2$ during physical restraint. A post-hoc analysis using the Wilcoxon test with Bonferroni correction was conducted for $EtCO_2$ values in the interventional measurements.

RESULTS

The initial (median) Forced Vital Capacity (FVC) value was 5.25 (L), decreasing to 3.86 (L) at the fifth minute of physical restraint, with a p-value of 0.005 (interventional measurements). The initial (median) FVC value was 5.31 (L), decreasing to 4.86 (L) at the fifth minute in the lateral position, with a p-value of 0.047 (control measurements). A significant decrease in FVC was recorded both during physical restraint in the prone position and in the lateral position without physical restraint.

The initial (median) Peak Expiratory Flow (PEF) value was 5.02 (L/s), decreasing to 3.76 (L/s) at the fifth minute of physical restraint, with a p-value of 0.005 (interventional measurements). A significant decrease in PEF was observed during control testing in the lateral position. The initial (median) PEF value was 4.371 (L/s), decreasing to 3.56 (L/s) at the fifth minute in the lateral position, with a p-value of 0.028 (control measurements). A significant reduction in PEF values occurred both during interventional and control measurements.

The initial (median) Forced Expiratory Volume in 1 second (FEV1%) value was 72.20%, which decreased to 69.05% at the fifth minute of physical restraint, with a p-value of 0.386 (interventional measurements). No significant decrease in FEV1% was observed. In the lateral position during control measurements, the initial (median) FEV1% value was 75.80%, decreasing to 58.30% at the fifth minute, with a p-value of 0.009. A significant decrease in FEV1% occurred only during control measurements.

Tab. 1. The results of the Bonferroni correction for pairwise measurements of $EtCO_2$ in the prone position at individual minutes. The statistically significant value corresponds to $p < 0.003$.

min	1	2	3	4	5
0	*p* = 0,013	*p* = 0,011	*p* = 0,005	*p* = 0,018	*p* = 0,007
1	x	*p* = 0,636	*p* = 0,314	*p* = 0,678	*p* = 0,919
2	x	x	*p* = 0,499	*p* = 0,281	*p* = 0,933
3	x	x	x	*p* = 0,176	*p* = 0,500
4	x	x	x	x	*p* = 0,499

There was no significant difference observed in respiratory rate during physical restraint in the prone position ($p = 0.176$) or in the lateral position ($p = 0.177$) (Figure 1). Statistically significant differences were noted in $EtCO_2$ values during physical restraint in the prone position ($p = 0.003$). No statistically significant differences were found in the lateral position ($p = 0.319$) (Figure 2). The observed statistical significance in the prone position is attributed to higher baseline $EtCO_2$ values. Bonferroni correction was applied to $EtCO_2$ values during intervention measurements, revealing no significant differences between $EtCO_2$ values (Table 1).

DISCUSSION

Studies of the risks of sudden death associated with the physical restraint of violent patients have been systematically published since the early 1990s. Several studies provide case reports of multiple sudden deaths during restraint by United States law enforcement officers, in the absence of obvious physical causes of death such as strangulation or pre-existing cardiac abnormality (Reay *et al.* 1992; O'Halloran and Lewman, 1993; Stratton *et al.* 1995). In 1997, Chan *et al.* were among the first to assess ventilatory function through spirometry in restrained individuals. Their study investigated pulmonary function tests (PFTs) in various positions, including sitting, prone, supine, and under restraint conditions, both before and after exercise. The results revealed statistically significant declines in Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), and Maximum Voluntary Ventilation (MVV) when subjects were placed in the Prone Maximal Restraint Position (PMRP). While subjects did exhibit a restrictive lung pattern in the restraint position, these changes were not deemed clinically relevant, and there was no evidence of hypoxemia or hypercarbia based on arterial blood gas measurements (Vilke, 2020). Barnett *et al.* (2013) published the results of a study involving patient restraint in three different prone positions. This study has demonstrated that all three prone restraint positions investigated imposed a degree of pressure on the anterior chest wall (PAC). All three prone-restraint positions imposed a degree of ventilatory restriction as measured by FVC and FEV1 when compared with baseline ($p < 0.001$). Our study demonstrated that a statistically significant reduction in spirometric parameters (FVC, FEV1%, and PEF) also occurs in the lateral position without external pressure on the chest. However, compared to restraining a proband in the prone position, the decrease in spirometric indicators was less pronounced.

From published studies, it is evident that there is a decline in spirometric indicators during physical restraint in the prone position. However, the absence of changes in respiratory rate and $EtCO_2$ indicates that the impact of physical restraint in the prone position on ventilatory functions is minimal. According to published studies, it seems that physical restraint in the prone position significantly influences the hemodynamic parameters of the patient. The prone position generates an increase in intrathoracic pressure, thereby decreasing venous return to the heart and thus decreasing cardiac output (Steinberg, 2021). Despite the fact that we only measured respiratory parameters, there is a study from the Czech Republic that also tested cardiac index, stroke volume index, stroke volume variation, systemic vascular resistance index and mean arterial pressure in twelve healthy volunteers older than 18 years (Kukrálová *et al.* 2021). All measurements were repeated in unsupported (P1 position) and supported (P2 position) prone positions with supported chest and pelvic regions. No differences in cardiac output and preload were detected after proning in unsedated healthy volunteers. Prone position was associated with changes of systemic vascular resistance, blood stagnation in jugular catchment area and, in unsupported prone position, increased collapsibility of inferior vena cava. The prone position can also lead to abdominal restriction and obstructed blood flow in the compliant inferior vena cava (IVC), thereby reducing preload and CO (Steinberg, 2021). This may be one of the main causes of the sudden death of a violent patient after physical restraint in the prone position. Many violent individuals who died after physical restraint in the prone position were markedly agitated. Agitation was associated with stimulant drug use. The combination of drug use and motor agitation results in a significant drop in blood pH. The rapid decrease in pH and the development of severe acidemia in the first few minutes of motor agitation may be another factor contributing to the sudden death of patients after physical restraint in the prone position (Steinberg, 2021).

In the context of evidence-based medicine, it is evident that physically restraining a patient in the prone position increases the risk of sudden death. Therefore, it should not be used for restraining violent patients in healthcare settings. Cardiopulmonary resuscitation of such patients is often very unsuccessful (Sin, 2018).

Our study has several limitations. Research was conducted on healthy and young participants. Physical restraint was carried out in simulated conditions. Participants were not under the influence of stimulant drugs or other psychiatric medications. Motor agitation did not precede physical restraint in the prone position. These factors limit the replication of real-life conditions where sudden death occurred in patients.

CONCLUSION

Kneeling of a violent patient is a risk factor for sudden death. In our study, we demonstrated that kneeling leads to a decrease in spirometric parameters. However, a decline in spirometric parameters also occurred in the lateral position without physical restraint. Physical restraint in the prone position should not be used in healthcare.

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DECLARATION OF COMPETING INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

REFERENCES

1 Barnett R, Hanson P, Stirling C, Pandyan AD (2013). The physiological impact of upper limb position in prone restraint. Med Sci Law. **53**: 161–165.
2 Barnett R, Stirling C, Hall J, Davies A, Orme P (2016). Perceptions of supported and unsupported prone-restraint positions. J Psychiatr Ment Health Nurs. **23**: 172–178.
3 Bartík P, Vostrý M, Hudáková Z, Šagát P, Lesňáková A, Dukát, A (2022). The Effect of Early Applied Robot-Assisted Physiotherapy on Functional Independence Measure Score in Post-Myocardial Infarction Patients. In Healthcare. **10**(5): 937.
4 Chan TC, Vilke GM, Neuman T, Clausen JL (1997). Restraint position and positional asphyxia. Ann Emerg Med. **30**: 578–586.
5 Knor J, Pekara J, Šeblová J, Peřan D, Cmorej P, Němcová J (2020). Qualitative Research of Violent Incidents Toward Young Paramedics in the Czech Republic. West J Emerg Med. **21**(2): 463–468.
6 Kukrálová L, Dostálová V, Dostál P (2021). Hemodynamic changes in the prone position - a non-invasive physiological study. Anest. intenziv. Med. **32**(2): 82–86. doi: 10.36290/aim.2021.010.
7 Kupas DF, Wydro GC, Tan DK, Kamin R, Harrell AJ 4th, Wang A (2021). Clinical Care and Restraint of Agitated or Combative Patients by Emergency Medical Services Practitioners. Prehosp Emerg Care. **25**(5): 721–723.
8 Meredith C, Taslaq S, Kon OM, Henry J (2005). The cardiopulmonary effects of physical restraint in subjects with chronic obstructive pulmonary disease. J Clin Forensic Med. **12**: 133–136.
9 NICE. Violent and aggressive behaviours in people with mental health problems. Quality standard [QS154]. Published: 29 June 2017. https://www.nice.org.uk/guidance/qs154 Accessed on?
10 O'Halloran RL, Lewman LV. Restraint asphyxiation in excited delirium. Am J Forensic Med Pathol. 1993;**14**: 289–295.
11 Parkes J (2008). Sudden death during restraint: do some positions affect lung function? Med Sci Law. **48**: 137–141.
12 Pekara J, Peran D, Cmorej P (2022). Comparison of Different self-defense Sprays in the Hands of paramedics – simulation Study. CSWHI. **13**(6): 43–48.
13 Pekara J, Peran D, Cmorej PCh (2022). Comparison of Different self-defense Sprays in the Hands of paramedics - simulation Study. Clinical Social Work and Health Intervention. **13**(6): 43–48.
14 Reay DT, Flinger CL, Stilwell AD, Arnold J. (1992). Positional asphyxia during law enforcement transport. Am J Forensic Med Patho. **13**: 90–97.
15 Sin R, Vodehnalova I, Ralbovska DCh, Struncova D, Cechurova L (2021). Out-of-hospital cardiac arrest in the Pilsen Region in 2021. Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub. **165**(1): 43–50.
16 Steinberg A (2021). Prone restraint cardiac arrest: A comprehensive review of the scientific literature and an explanation of the physiology. Med Sci Law. **61**(3): 215–226.
17 Stratton SJ, Rogers C, Brickett K, Gruzinski G (2022). Factors associated with sudden death of individuals requiring restraint for excited delirium. Am J Emerg Med. 2001;**19**: 187–191.
18 Stratton SJ, Rogers C, Green K (1995). Sudden death in individuals in hobble restraints during paramedic transport. Ann Emerg Med. **25**: 710–712.
19 Vilke GM (2020). Restraint physiology: A review of the literature. J Forensic Leg Med. **75**: 102056.
20 Vostrý M, Lanková B, Zilcher L, Jelinková J (2022). The Effect of Individual Combination Therapy on Children with Motor Deficits from the Perspective of Comprehensive Rehabilitation. Applied Sciences. **12**(9): 4270.