EXTENDING THE EXPIRATORY DATE ON **PRONE-RESTRAINT CARDIAC ARREST**

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In our previous *BLUE LINE* article entitled *Prone Restraint and Positional Asphyxia in Custody Deaths* GTD Scientific reviewed studies in which cardiorespiratory variables were measured during simulated prone restraint, which provided evidence that recovery from exercise while relaxed and restrained does not differ appreciably from recovery from exercise while seated. However, these studies are limited in at least three fundamental aspects. First, a prone-restrained detainee is often not relaxed or recovering from exertion. Rather, the detainee is often actively struggling while prone-restrained. Second, the prone-restrained detainee is not being passively restrained. Rather, the detainee often has several law enforcement personnel actively suppressing any movement which the detainee attempts to make. Third, the detainee generally does not belong to the same demographic group as the subjects of these studies, who are generally young, healthy and not overweight. Additional factors, such as emotional distress and substance use were not addressed in these studies.

Rather than further critiquing these studies, it is instructive to examine a study which more closely replicated real world prone restraint [1] and systematically analyze the results in relation to cardiorespiratory processes. In that study, subjects were instructed to perform a maximal struggle for 60 seconds while prone-restrained. Oxygen consumption ($\dot{V}O_2$), minute ventilation ($\dot{V}_E$) and heart rate where measured, as well as the respiratory exchange ratio (RER). All of these measures increased monotonically during the 60-second struggle. On average $\dot{V}O_2$ and $\dot{V}_E$ reached approximately 40% of their corresponding values during a maximal treadmill test, whereas heart rate reached almost 85%. The authors concluded that subjects had adequate ventilatory reserve up to the termination of the 60-second struggle. First, it is important to point out that $\dot{V}O_2$, $\dot{V}_E$ and heart rate were still increasing when the struggle terminated, suggesting that they would have attained higher values had the struggle continued. Second, the RER was 1.16, on average. implying that CO_2 production was high. Third, the authors conceded that they "could not reproduce the psychological or other physiologic stresses associated with a field pursuit, struggle or trauma", but more critically, the restraint was passive and no load was applied to the subjects' back.

Consider the implications of these issues from the perspective of respiration mechanics. CO_2 production would have been even higher if the struggle had progressed beyond 60 seconds. Consequently, the work of breathing would have to increase to expire more CO_2. A load on the back would add to the work of breathing and reduce respiratory efficiency. It has been shown that in the prone position functional residual capacity (FRC) is reduced compared to upright or seated positions, but more critically it decreased progressively throughout a 5-minute recovery period following exercise while subjects were in a prone-restrained position with a 35% body-weight load [2]. Large reductions in FRC predisposes an individual to partial lung collapse, reducing tidal volume and, hence, the amount of CO_2 which can be expired. It has been suggested that FRC reduction requires that more work must be done by inspiratory muscles, resulting in greater CO_2 production. It would, therefore, appear that while the production of CO_2 increases during a struggle in the prone-restrained position, the amount of CO_2 which can be expired decreases. This puts the detainee at increased risk of respiratory and metabolic acidosis.

The contribution of factors such as obesity, active restraint, emotional distress and substance use should not be ignored. Obesity by itself reduces FRC so placing an obese individual in a prone restrained position will compound the effect of progressively declining FRC during restraint. When law enforcement personnel are actively suppressing body movement by applying force, they not only increase the work of breathing because the detainee must apply greater forces to create the necessary respiratory movements, but panic can ensue, similar to that reported by patients paralyzed while awake under general anesthesia. Panic tends to increase heart rate and breathing frequency. The former will increase CO_2 production, while the latter will increase the work of breathing by reducing respiratory efficiency. Substance abuse can blunt normal physiological responses that regulate blood acidity in response to increasing CO_2 production. Thus, a prone restrained individual who is obese, actively restrained, in emotional distress and/or using methamphetamine, opioid or cocaine will be further compromised in being able to expire CO_2, placing them at increased risk of cardiac arrest due to respiratory or metabolic acidosis.

[1] Michalewicz BA, Chan TC, Vilke GM, Levy SS. Neuman TS, Kolkhorstet FW (2007) Ventilatory and metabolic demands during aggressive physical restraint in healthy adults. J Forensic Sci 52(1): 171–175.

[2] Campbell M, Dakin R, Stowe S, Burton K, Raven B, Mapani M, Dawson JW, Adler A (2021) Thoracic weighting of restrained subjects during exhaustion recovery causes loss of lung reserve volume in a model of police arrest. Sci Rep 11:15166.

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