Applied Force During Prone Restraint

Is Officer Weight a Factor?

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Introduction: It has been suggested that law enforcement officer (LEO) weight on the backs of prone subjects may cause asphyxia.

Methods: Law enforcement officers used their agency-trained "local" single- and double-knee techniques, the "Wisconsin" 3-Point Ground Stabilization, and the Human Factor Research Group Inc single-knee tactical handcuffing techniques, and the weight force was measured.

Results: Forty-one LEOs (36 men, 5 women) participated, aged 38.4 ± 8.3 years, and weighing 96.2 ± 19.4 kg. The double-knee technique transmitted more weight than single knee ($P < 0.0001$). Wisconsin technique force was lower than other single-knee techniques ($P < 0.0001$). Double-knee weight was 23.3 kg plus 24% of LEO's body weight. Mean values for local and Human Factor Research Group Inc single-knee were 30.9 and 32.9 kg, respectively. The Wisconsin single knee weight force was given by 15.4 kg plus 9.5 kg for a male.

Conclusions: A double-knee technique applies more weight force than single-knee techniques. The Wisconsin single-knee technique provides the least weight force of single-knee techniques. Law enforcement officer body weight is irrelevant to prone-force weight with single-knee techniques. With double-knee restraint, it has a modest influence. Our data do not support the hypothesis of restraint asphyxia.

Key Words: compressional asphyxia, positional asphyxia, prone restraint, restraint asphyxia

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North American law enforcement officers (LEOs) control and restrain agitated and resistant subjects in the prone position more than 500,000 times each year without a death or serious injury.[1–4] Prone restraint is a standard technique taught in criminal justice academies and through in-service training courses and is often preferred to facilitate control and restraint of resistant subjects in handcuffs secured behind their back. The restraint process may involve 1 or 2, and sometimes more, LEOs placing a single or both knees on the subject's back or kneeling next to the subject to control the subject's movements, hands, and arms to facilitate handcuffing. If necessary, the subject's ankles may also be restrained with a hobble strap.[5] It is largely based on Fairbairn's[6] scientific self-defense system dating back to 1926, updated in 1931. Once the restraint process has been completed, and depending on the subject's continuing resistance, LEOs may place the subject into a recovery position (side lying) or assist the person to a standing or a seated position to faciliate medical assessment and treatment.

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Epidemiology

Law enforcement officer force is rare, but prone positioning is common when force is used. In the United States in 2008, there were 562,000 incidents (1 per 71 contacts) with police in which force was used or threatened. In a US study of more than 1 million calls for service, force was used in 893 incidents, (0.09% of calls) and 0.8% of 114,000 criminal arrests (1 in 128).[4]

In Ross and Hazlett's[3] study of 110,000 US arrests, 1085 incidents resulted in prone positioning. Lasoff et al[2] report that of 2431 force incidents, 1535 subjects (63%) ended up being placed in a prone-restraint position. Approximately 80% of resistant subjects have comorbidities of mental illness, drug abuse, or intoxication (most have ≥2 of these).[7,8] In Canada, Hall et al[1] reported on 3.25 million consecutive police-public interactions; force was used with 4828 subjects (0.1% of police-public interactions), and 82% exhibited alcohol or drug intoxication or emotional distress at the scene. More than 2000 subjects remained prone after handcuffing. Despite these significant comorbidities, these studies reported no deaths linked to prone restraint.

Arrest-related death (ARD) is significantly rarer than the use of prone restraint. Annually in the United States, there are about 800,000 forceful arrests and 800 temporal ARDs, yielding a mortality rate of ≈1:1000. The rate for electrical weapon temporal ARDs is estimated to be 1:3500.[9–11] Virtually every use of force poses some risk of death. Krexi et al[12] report that in stress-induced sudden cardiac death 45% involved altercation, 31% had physical restraint, and 10% were in police custody, with 53% of all cases having a negative (normal) autopsy and a morphologically normal heart. Sudden death from metabolic and adrenergic stress is not confined to the targets of law enforcement. In a 25-year study of US LEOs, Varvarigou et al[13] reported that – compared with routine activities– the risk of LEO sudden death was 34 to 69 times higher during restraint or an altercation.

The Controversy

If a person dies temporal to law enforcement custody during control and restraint, a thorough investigation follows. An ARD, after restraint, comprises multiple factors to review, including the force techniques; postmortem findings and toxicology results; the subject's underlying medical, psychological, and chemical substance history; conditions during the restraint confrontation; and the continued levels of agitation and resistance exhibited during and after restraint processes.[14,15] Even a thorough autopsy may find no apparent anatomical or toxicological causes of death and the medical examiner then may theorize about the cause or contributing factors of death. Although the medical examiner may exclude many of the LEO's force measures as contributing to death, it is not uncommon for them to opine—or in an abundance of broad inclusion—to include prone restraint as contributory to the death. We note that the medical examiner opinion is typically referred to as a "finding."

When a cause of death cannot otherwise be determined, positional asphyxia is often suggested. True positional asphyxia has occurred in individuals found in an abnormal body position preventing adequate gas exchange due to an upper airway obstruction or a limitation in chest wall expansion.[16,17] The term "positional asphyxia" was imported into law enforcement usage and later randomized to "restraint asphyxia" and "compression asphyxia," often through causally unreliable case reports and case series.[18–27] These semantic modulations were forced on law enforcement arrest and restraint situations attempting to support speculations that short-term downward pressure on a subject's back caused or contributed to sudden death. Proponents of this theory often hypothesize that subjects restrained prone, with applied downward weight force, hobbled, or in maximal restraint (restrained on their stomach with hands and wrists secured to the handcuffs) were unable to breathe because the position caused chest wall and abdominal restriction that prevented adequate expansion of the lungs.[27–31] Subsequent rigorous scientific studies, however, using sophisticated measurements have debunked the positional or restraint asphyxia hypothesis because the prone position does not produce respiratory compromise.[24,25,32,33]

Despite significant research showing that the prone-restraint position per se is physiologically neutral, the concern has shifted to the risk of death due to "compression" asphyxia from the LEO's weight. Clinical studies have assessed human subjects in the prone-restraint position with weights from 45 to 102 kg (100–225 lb) placed on their back over several minutes. No evidence of clinically significant respiratory impairment, hypoxia, hypoventilation, or venous return has been found.[34–38] Prone maximal restraint also appears safe in obese subjects.[39] Epidemiological studies are consistent with these clinical findings, and these studies refute the hypothesis that prone position, temporary weight force, hobble restraint, and maximal restraint are inherently dangerous.[1–3]

There is societal interest in guiding LEOs toward safer and more effective methods of capturing, controlling, and restraining agitated or resistant persons. With this interest in mind, we evaluated the amount of single-officer human weight-force pressure applied on a training mannequin in prone position during simulated handcuffing.

METHODS

We measured downward weight-force pressure of 4 exemplar single-officer ground-prone restraint techniques commonly utilized by LEOs to place downward kneeling pressure (weight force) on a simulated-resistant prone subject: (1) local double knee, (2) local single knee, (3) single-knee "Wisconsin" Defensive and Arrest Tactics (DAAT) 3-Point Ground Stabilization technique, and (4) single-knee Human Factor Research Group Inc (HFRG) tactical handcuffing technique.[40,41] The local techniques were those used by the participating Plymouth (Minn) Police Department.

Study participants were a convenience volunteer sample of active Minnesota LEOs during their in-service training (n = 35), as well as 6 recruits attending a law enforcement academy. Data on participants' age, height, standing weight, and sex were collected. Because data collection was run in parallel with physical tactics training, the ordinal sequence was used as a predictor to neutralize training effect.

The simulated subject was a Simulaids Rescue Randy training mannequin, 165 cm (65 in.) in height and weighing 46 kg (102 lb), supplied by OregonCPR, placed prone on an Intercomp Speedway electronic scale system of 4 small platforms in series. The height of the scales from the floor surface was offset by training floor pads to simulate the mannequin being flat on the floor surface, more accurately simulating a prone human subject (Fig. 1).

Prior to each downward weight measurement, the specific technique to be performed and measured was explained to the participants, and they were asked if they had any questions, which were answered to participants' satisfaction. The participants were instructed that they could take as much time as they wanted to position themselves into the optimal position for the specific technique. Once stationary, they were instructed to do their best to hold the position with consistent normal downward pressure for 30 seconds until they were instructed to relax. The scales were rebalanced after each measurement. The scales were programmed to average 8 readings to give stable readings, and the last (averaged) reading was recorded.

Participants used the local double- and single-knee control techniques as shown in Figure 2. They then used the Wisconsin DAAT 3-Point Ground Stabilization and the HFRG single-knee techniques as shown in Figure 3. The Wisconsin DAAT 3-Point Ground Stabilization technique is similar to the local single-knee technique, except the DAAT technique involves LEOs placing their left knee in direct contact next to the subject's elbow to stabilize the elbow for a compression hold, emphasizing that most of their weight should be on the supporting stabilizing knee, and as they perform the technique intentionally keeping their weight on the ball of their stabilizing foot. The HFRG technique is similar to the local single-knee technique, except that the LEO faces the subject's lower body and the LEO's shin is close to the subject's head. Human Factor Research Group Inc also teaches a double-knee technique, which was not evaluated in this study.

Ethics

The study was performed under an exemption from the University of Minnesota Institutional Review Board. No compensation or inducement was provided. All subjects signed a consent form. Photographed subjects provided written consent allowing the publication of their likeness.

Statistical Analysis

Tukey outliers of prone-force weight readings were excluded. Univariate significance was defined by $P < 0.05$, and paired comparisons were done by the Wilcoxon signed rank test. Multivariate

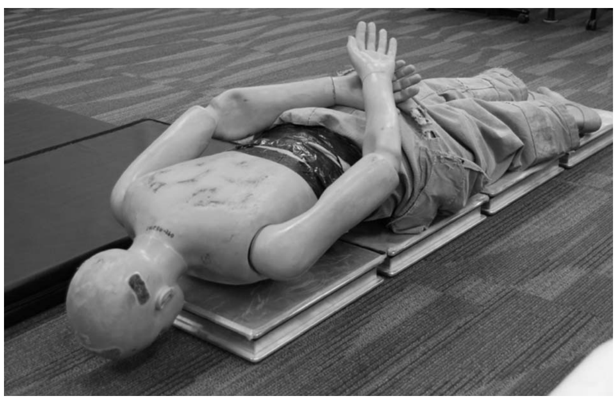

FIGURE 1. Mannequin on low-profile scales with height-equalizing pads.

FIGURE 2. Local handcuffing techniques. Double knee (A) and single knee (B).

significance required $P < 0.1$ and a correlation increase of $r^2 \geq 0.02$. Predictors evaluated were age, standing weight, sex, body mass index (BMI), and sequence offset. The sequence offset was −20 for the first LEO of the study and +20 for the last. Because BMI competes for variance with weight, we also analyzed the prone weight with BMI left out.

RESULTS

Data on 41 LEOs (36 men, 5 women) were collected. Age was 38.4 ± 8.3 years with a median of 39 years (interquartile range [IQR]: 32–45 years). Height was 180.0 ± 8.0 cm with a median of 183 cm (IQR: 175–185 cm). BMI was 29.4 ± 4.4 kg/m^2 with a median of 28 kg/m^2 (IQR: 26–33 kg/m^2). Weight was 96.2 ± 19.4 kg with a median of 90 (IQR: 82–118 kg [212 ± 43 lb; median, 198 lb with IQR of 181–259 lb]).

There were 3 Tukey outliers in the kneeling data, and they were excluded. With the local single knee, these were subject 37 (65 kg) and subject 15 (69 kg). Subject 3 had a Wisconsin single-knee weight of 62 kg, and this datum was also excluded. There were no outliers with the double-knee or HFRG weights. After these 3 exclusions, the kneeling-force weights were as shown in Table 1. The double-knee weight was greater than all single-knee techniques

FIGURE 3. Other handcuffing techniques. Wisconsin (A) and HFRG (B) single-knee techniques.

TABLE 1. Summary Force Statistics (kg)

	Mean ± SD	Median	IQR	Min	Max
Double knee	46.6 ± 13.3	48	39–55	17	73
Local single knee	30.9 ± 12.0	33	22–38	7	55
Wisconsin single knee	23.7 ± 11.5	23	15–31	4	50
HFRG single knee	32.9 ± 14.2	34	22–41	5	67

with $P < 0.0001$. The local single-knee technique was not distinguishable from the HFRG ($P = 0.43$ by Wilcoxon signed rank test). The Wisconsin technique weights were significantly lower than the other single-knee techniques with $P < 0.0001$.

The LEO standing weight distribution was bimodal and highly non-Gaussian (Shapiro-Wilk $P = 0.008$) (Fig. 4). For this reason, we analyzed the results with 3 groupings based on standing weight: lumped, lower 3 quartiles of weight, and heavier officers (weight >90 kg). Summaries are shown in Table 2 (in kilograms) and Table 3 (in pounds).

Lumped Analysis

The double-knee force was predicted by an intercept of ≈10 kg plus ≈10 kg for a male and 0.94 times BMI. When BMI was forced out, the predictors were 23.3 kg plus 24% of the LEO's body weight.

The local and HFRG single-knee forces were not correlated with any of the predictors but rather best predicted by intercepts of their mean values of 30.9 and 32.9 kg, respectively. The Wisconsin single-knee weight was predicted by an intercept of 15.4 kg plus 9.5 kg for a male.

Lower 3 Quartiles Analysis

The lower 3 quartiles produced a fairly Gaussian distribution (n = 31) with a Shapiro-Wilk statistic of 0.19 and a mean weight of 87.7 ± 13.9 kg. The double-knee force was predicted by an intercept of −0.9 kg (negative 0.9 kg) plus ≈10 kg for a male and 1.36 times BMI. When BMI was forced out, the predictors were 34.7 kg plus 12.6 kg for a male.

As with the lumped analysis, the local and HFRG single-knee forces were not correlated with any of the predictors but rather best predicted by intercepts of 32.4 and 32.8 kg, respectively. The Wisconsin single knee was predicted by an intercept of 29.1 kg plus 10.8 kg for a male less 0.42 kg per year of LEO's age.

Heavier Officers (Weight >90 kg) Analysis

Limiting the group to a weight of greater than 90 kg (198 lb) produced a less bimodal distribution (n = 20) with a Shapiro-Wilk statistic of 0.05 with mean weight of 113.4 ± 11.5 kg. Because of the small subgroup sample size, the following statistics should be considered with some circumspection. The double-knee, Wisconsin, and HFRG single-knee forces were not correlated with any of the predictors but rather best predicted by intercepts of 51.2, 24.9, and 33.9 kg, respectively. The local single-knee force was predicted by an intercept of 81.2 kg less 45% of the LEO's weight. That fit was judged to be a spurious overfit, and it was removed, leaving an intercept value of 30.5 kg for the predictor.

DISCUSSION

We believe that this is the first study to present the actual weight force applied during single-officer prone subject handcuffing. A surprising and key finding was that the prone force applied had almost zero correlation with the LEO's weight. Only with the double-knee technique was the LEO's weight relevant, with 24% being transferred to the prone subject with the lumped analysis. In none of the single-knee techniques was there any positive correlation of LEO weight with the prone force. In force-involved litigation, the weight of the LEO, including all equipment, is often stressed if the LEO is heavy. That presumption—that a large fraction of the LEO's weight is transferred—stands refuted by these data.

Another finding was that male LEOs presented about 10 kg (22 lb) more downward force than female LEOs with some techniques (double knee and Wisconsin for the lumped and lower 3-quartiles groups). An interesting result was that the double-knee force increased during the day of testing as shown by the sequence-offset variable. This was seen with the lumped population and with the lower 3-quartiles but not with the LEOs

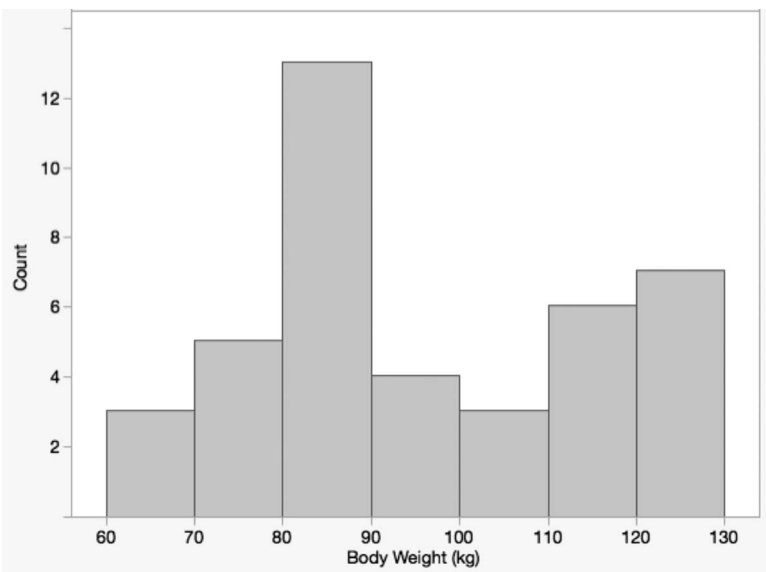

FIGURE 4. Officer weight distribution (in kilograms) was bimodal.

TABLE 2. Multivariate Fits to Prone Force (kg)

	Technique	r^2	RMS Error	Intercept, kg	Male	Age, kg/y	Weight	BMI	Sequence Offset
Lumped	Double knee	0.35	11.1	9.9	10.2			0.94	0.46
n = 41	(BMI forced out)	0.27	11.6	23.2			0.24		0.44
	Local SK		12	30.9					
96.2 ± 19.4 kg	Wisconsin SK	0.08	11.1	15.4	9.50				
	HFRG SK		14.2	32.9					
Lower 3Q	Double knee	0.43	10.9	−0.9	10.3			1.36	0.59
n = 31	(BMI forced out)	0.35	11.4	34.7	12.6				0.52
	Local SK		12.5	32.4					
87.7 ± 13.9 kg	Wisconsin SK	0.18	10.3	29.1	10.8	−0.42			
	HFRG SK		13.9	32.8					
>90 kg	Double knee		11.2	51.2					
n = 20	Local SK		10.7	30.5					
	Wisconsin SK		11.7	24.9					
113.4 ± 11.5 kg	HFRG SK		14.6	33.3					

SK indicates single knee.

weighing more than 90 kg. Because the study was run in parallel with defensive-tactics training, we speculate that LEOs became slightly more aggressive as the day progressed. Notably, no such increase was seen with the single-knee techniques. Older LEOs tended to provide less force with the Wisconsin technique as seen in Tables 2 and 3.

The transferred weight is highly dependent on the technique used. The double-knee technique provided about double (2×) the weight of the Wisconsin single-knee technique. This is likely because the Wisconsin technique emphasizes intentional maintenance of weight on the stabilizing leg. Other single-knee techniques lie in between.

Instrumented breathing studies have shown that back weights up to 102 kg (225 lb) do not cause clinically significant interference with breathing.[37] The maximum transferred weight measured was with the double-knee technique, and that was 73 kg (161 lb).

Asphyxial death requires mechanical factors that either occlude the airway or prevent the usual movement of the chest wall and diaphragm for breathing. Asphyxia also involves impaired blood flow affecting the brain. This can occur in any position, including the seated position. This may also occur, in heavily intoxicated subjects who "pass out" with their airway occluded. The term "positional asphyxia" was classically used to describe the death of individuals who were found in circumstances with truly compromised respiratory function. Compression asphyxia is also a genuine phenomenon that has caused many deaths. However, these deaths have occurred from auto accidents, building collapse, cave-ins, crowd crush, and occupational accidents.[42,43]

To date, none of the published human clinical studies, or epidemiological studies, support the hypothesis that the prone-restraint position causes or contributes to ventilatory compromise. When gas exchange is severely impaired in critically ill lung-disease patients, they are commonly repositioned to receive ventilation in the prone position rather than in the supine position as the prone position improves gas exchange.[44–47]

We have previously published on the issue of compressional asphyxia and the weight needed to cause death.[48,49] Weights of 170 to 182 kg (375–400 lb) on the chest are survivable because of diaphragmatic breathing. Weight force beyond 260 ± 26 kg (573 ± 57 lb) would cause sufficient rib fractures for fatal flail chest. Applying this to prone restraint suggests that it would take

TABLE 3. Multivariate Fit With Pounds and BMI Excluded

		Intercept, lb	Male, lb	Age, lb/y	Weight, %
Lumped	Double knee	51			24
	Local SK	68			
	Wisconsin SK	34	21		
	HFRG SK	73			
Lower 3Q	Double knee	77	28		
	Local SK	71			
	Wisconsin SK	64	24	−0.93	
	HFRG SK	72			
>90 kg	Double knee	113			
	Local SK	67			
	Wisconsin SK	55			
	HFRG SK	73			

SK indicates single knee.

2 or more LEOs each weighing 130 kg (287 lb) standing and balancing on the back of a prone subject to produce true compressional asphyxia via flail chest.

Even with significant weight applied with both knees placed on the back of a subject, an individual can breathe well with diaphragmatic or "belly" breathing. In fact, breathing is primarily abdominal. Deep breathing is more thoracic (chest-based) in females but more abdominal in males. In other words, even if the chest is restricted, we can survive with abdominal breathing. If both the chest and the abdomen are restricted for more than 4 minutes, a person may die of asphyxia. That is seen in crowd-crush incidents and is well documented on surveillance videos.

Our results are supported by prospective field research studies that examined the outcome of prone restraint with violent subjects.[1–4] Collectively, these studies found that law enforcement use of force is rare and that the prone position was safe—with no deaths—and treatable injuries were sustained in fewer than 25% of the subjects. Law enforcement officers in these 4 studies used various force measures to control the subject, including: empty-hand control techniques, oleoresin capsicum spray, electrical weapons, impact weapons (eg, baton), canines, handcuffs, and a hobble strap. Only in the study of Hall et al[1] did a subject die, and he was not in a prone-restraint position. The study of Ross and Hazlett[3] also showed that the weight of LEOs on the back of the subject in the prone-restraint position, for about 1 to 5 minutes, and with about 20% of the subject's ankles hobbled, did not create adverse physiological effects. The collective conclusion of these clinically consistent field studies shows that using the prone-restraint position did not increase the risk of harm.

DiMaio and DiMaio[50] observed that acceptance of the concept of positional asphyxia as the cause of death in restraint-associated deaths often involves the suspension of common sense and logical thinking. Further, other researchers have commented that positional asphyxia is an interesting theory unsupported by the experimental data.[18,51] Nor are significant changes in cardiovascular measures found. It is important to be aware of the potential for airway occlusion, including in the prone position, but it is not inherently more dangerous than any other position. In fact, in a severely altered person, the chance of airway compromise by the tongue or vomitus is a concern in the supine position. Simply placing knees on the back of a prone and actively resisting subject and controlling the legs do not impede the person's ability to ventilate.[5]

Our findings continue the ongoing refutation of the speculation that using the prone-restraint position, with officer weight placed on the back, presents an increased risk of harm.

Limitations

It is probable that different weights could have been obtained with an actual struggling subject or with multiple-officer techniques. It is difficult to say whether those weights would have been higher or lower. Law enforcement officers may be tempted to push down harder with a struggling subject. On the other hand, LEOs could be more concerned about a loss of balance and thus apply less knee force. Also, this study did not include objective measurements of the effectiveness of each technique. The effectiveness of a given technique must be balanced against the risk of the technique. For example, Barnett et al[52] proposed "safer" prone arm positioning, which unfortunately would not be compatible with handcuffing.

CONCLUSIONS

Single-officer double-knee techniques apply slightly more weight force than single-knee techniques. The Wisconsin single-knee technique provides the least weight force of the single-knee techniques tested. Law enforcement officer body weight is irrelevant to applied prone-force weight with single-knee techniques. With double-knee restraint, it has a modest influence. Prone force weight—with various handcuffing techniques—is less than that demonstrated safe for breathing. Our data do not support the concept of restraint asphyxia.

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