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Post-Mortem Repositioning of Human Bodies in Fires

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Abstract
One of the indicators forensic fire investigators try to use in the reconstruction of fatal fires is interpreting the position of a burned body and its limbs in a fire scene. Both scene investigators and forensic pathologists have attempted to reconstruct the final moments of the victim's life by examining the remains – sometimes as the remains are documented at the scene, but often after recovery, removal, transport, and delivery to the morgue. These later processes can alter or even destroy badly burned remains to such a state that any interpretation is guesswork. Even more distressing is the lack of empirical knowledge about the effects of fire on a body during an actual fire. Because very few forensic personnel have ever watched a deceased body burn in a fire and with such limited empirical data, it is not surprising that much of the attempted reconstruction is guesswork and misinterpretation. The author has been part of the annual Forensic Fire Death Investigation Course (FFDIC) offered in San Luis Obispo, California since 2008. The field exercise of this unique course involves the preparation of 10 to 12 different fire scenes in which one or two unembalmed human cadavers are exposed to each fire. The events include structure (room and contents) fires – often to flashover and beyond. Others include road-side dumps and vehicle body disposal. Some fires are brief in duration – 10-20 minutes – some involve 6-8 hours of fire exposure. These classes have given the author and other instructors the unique opportunity to observe numerous bodies of unembalmed adults during the course of a wide variety of real-world 'fatal' fires. This paper will illustrate a sample of the effects of fires (structure, vehicle, and bonfire) on the position of bodies and how the positions of limbs, heads, and sometimes torsos can change during the course of fire exposure.

Keywords: Fire, Fatal, Repositioning, Bodies, Pugilistic Posturing

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Introduction:
The effects of fires on bodies include thermal destruction that can range from minor changes to the epidermis to destruction of soft tissues and bones. The changes in physical position due to exposure to heat are called pugilistic posturing (in reference to the hunched back, flexed knees and raised arms often seen in fire victims). It is often observed in fire cases, but interpretation is subject to error because:
1: The position seen at autopsy is thought to be the position at the time of death.
2: There is a failure to realize the effects are the result of strictly mechanical effects as the heat shrinks the connective tissues (muscles, tendons, and ligaments at the joints).
3: The position is thought to reflect physical activities of the victim prior to death.
4: There is a lack of observational data about bodies in real-world fires (often what there is is what is observed during legal cremations (1,2)
Such cremations do not replicate the variety of fire exposures created during real-world fires. It is the objective of this paper to present observational data on the effects of real-world fires on unembalmed human cadavers.
The author was part of the annual Forensic Fire Death Investigation Course (FFDIC) offered in San Luis Obispo, California from 2008-2015. The field exercise of this unique course involves the preparation of 10 to 12 different fire scenes in which one or two unembalmed human are exposed to each fire. Some fires are brief in duration – 10-20 minutes – some involve 6-8 hours of fire exposure. The events include structure (room and contents) fires – often to flashover and beyond. Others include road-side dumps and vehicle body disposal. After extinguishment, teams of students, including fire investigators, homicide detectives, medicolegal personnel and sometimes forensic

scientists (forensic anthropologists in training) are selected. Each team is assigned a scenario and is expected to document and search the scene and reconstruct the events of both the death and the fire. These classes have given the author the opportunity to observe dozens of bodies of unembalmed adults during the course of a wide variety of real-world 'fatal' fires.

It is the effect of heat (whether it is transferred to and through the body tissues by radiant, conductive, or convective heat transfer processes) on the tissues of the body that are of concern here. Most of the effects are seen as the result of actual fires, but victims trapped in hot enclosures (chimneys, heating ducts, or ovens) can display the same effects. The human body presents a complex fuel package to a hostile fire, with layers of different materials (skin – epidermis and dermis, subcutaneous fat, muscle and tendons, and bones) that react in characteristic ways and repeatable sequence to a fire. The thermal characteristics of these materials vary from one to another. The epidermis separates and burns away quickly, but the dermal layers require 5-7 minutes of normal fire exposure before they shrink and split to expose the subcutaneous fat beneath.[3] That fat is the best thermal insulator and also the best fuel within the body and has been observed to sustain flaming combustion on and around the body for 6-7 hours if there is a suitable wick present.[4] Burning of petrol poured on bare skin does not sustain a flame long enough to do more than scorch the dermal layers. [5]

The thin tissue around joints fails very quickly in a general fire exposure. The tendons and ligaments thus exposed shrink to cause flexion of the joints. As the fire progresses, the muscles shrink from the heat and major joints start to flex. One significant observation of these tests is the amount of pugilistic posturing that occurs during many fires. The post-fire position of the head, arms and legs is often very different from the pre-fire position (as a caution against judging the position of the body as proof of living reaction to the oncoming fire). If supported on a mattress or a chair cushion in a prolonged room-and-contents fire, some cadavers have been observed to end up on the floor. It has been observed that roadside 'dumps' (fueled by tires, tree limbs, and wood pallets), trash barrel fires, or vehicle fires, can incur considerable destruction of an exposed body in only 1-3 hours. Most, if not all, of the soft tissue can be consumed or completely charred and the bones will be calcined to the point of fragility.

The contraction of tendons, ligaments, and muscles from heat is not strong enough to cause the fracturing of healthy, unburned bone. Fresh bone is a composite of mineral (for strength and rigidity) and organic components (collagen) for resilience. Heat destroys first the organic components – by evaporation, charring, pyrolysis, and combustion and then dehydrates the bone, ultimately destroying the chemical structure of the minerals themselves. This process is termed calcination and leaves the bones fragile enough to be broken by the stress of movement or touch. Bones that are fractured before fire exposure can be displaced by the shrinkage of the attached tissues.[4]

Methods and materials:

A variety of fire scenarios is created each year for the FFDIC course by the instructors to give the students exposure to different fire scene conditions. These can range from body disposals in burning automobiles, to roadside dumps fueled by brush, wood pallets, tires, and trash), to furnished rooms ignited by a number of different mechanisms to recreate both accidental and intentional fires. The rooms were purpose-built using wood studs and gypsum wallboard wall- and ceiling coverings. The furniture and clothing was obtained second-hand from local donation centers. Each room or vehicle was fitted with thermocouples to record temperatures (with one usually placed in the center of the upper torso to record internal body temperatures). Unembalmed human cadavers refrigerated at near 0°C, were dressed and positioned in various positions suitable for the scenario*. It was necessary to use unembalmed cadavers since the embalming process hardens the tissues, preventing their normal reaction to heat.

Each scenario was photographed prior to, during, and after the fire. The post-fire appearance of the remains was examined by a forensic anthropologist prior to disturbance by the student investigative team. Each fire was burned to the extent desired by the instructors and then extinguished with normal water suppression (modified fog stream was used to minimize destruction of fragile remains). Some of the cadavers were exposed to a limited fire confined to the bed or upholstered furniture on which they lay. Others were exposed to a post-flashover compartment fire where all fuels in the compartment were on fire and burning as quickly as oxygen could be supplied. These fires routinely reach temperatures of 900-1000C throughout the compartment and the radiant heat intensity is on the order of 150kW/m2 or more. [6]

A summary of the tests represented here is shown in Table 1.

Results:

Over fifty human cadavers have been observed over the period 2008-2015 in various fire exposures. Some fires produced minimal repositioning due to the position of the body, restraints, or short duration of the fire exposure. The results of twelve selected fires are best demonstrated by the photographs taken prior to (sometimes during), and after each fire.

Scenario: The cadavers were obtained by the Medical Education and Research Institute,(MERI), Memphis, TN as specified donations and provided to the San Luis Obispo County Sheriff -Coroner Office in accordance with applicable medical ethical guidelines for use in the FFDIC class only. At the end of the course, the remains were resealed in their original body bags and transported back to MERI for cremation.

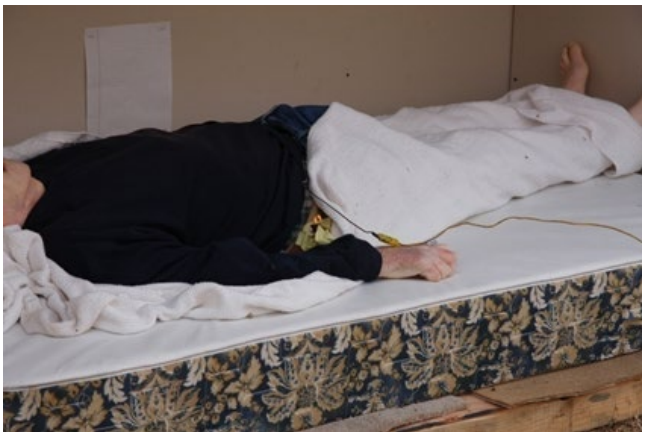

Figure 1: Test 1: Sustained fire on bed. Body of elderly male adult, dressed in cotton sweat shirt and pants on modern box spring, covered with cotton blanket. Body in supine position with legs extended straight and arms by sides. Fire ignited with open flame to paper at edge of blanket. Fire duration was 7 hrs (self-extinguished).

Figure 2: Test 1: At 16min, the right arm is raising at the elbow and the legs are flexing upward due to flexing of the knees

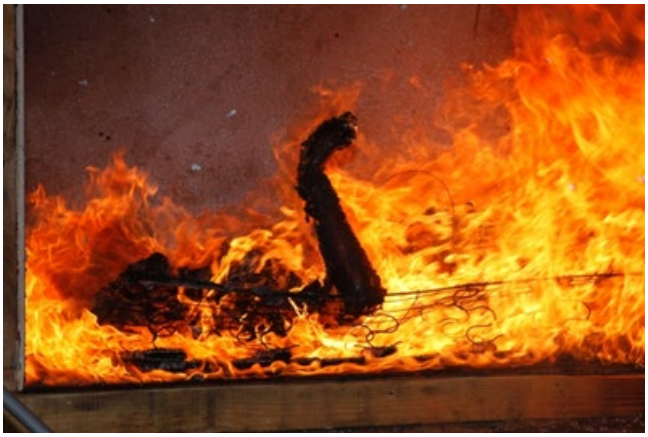

Figure 3: Test 1: At 21min, right arm is raised. Fingers are disarticulated

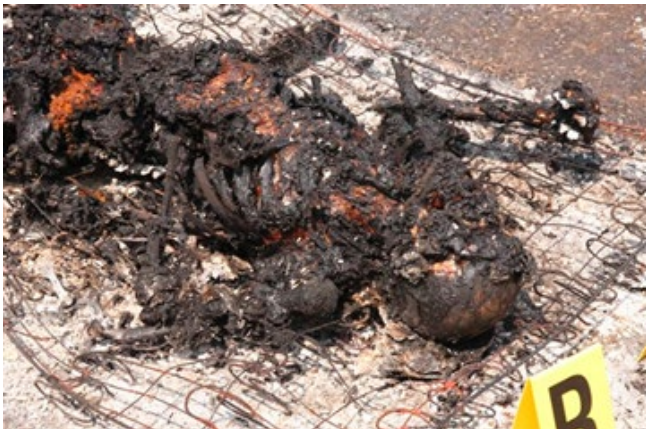

Figure 4: Test 1: After self-extinguishment at 7hrs, both arms are flexed at shoulders and elbows. Hands are in a very different position than at the start

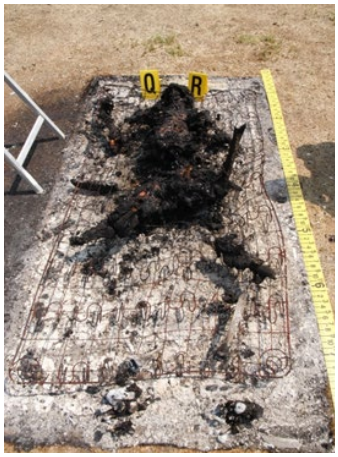

Figure 5: Test 1: The feet are disarticulated, the knees are flexed outward. The left femur was broken mechanically before the fire and it is in an upright position to the body

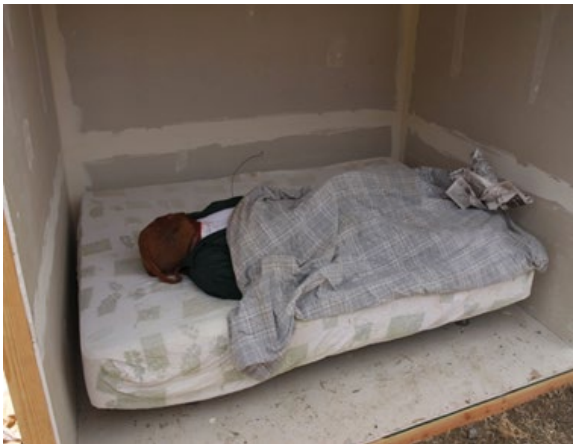

Figure 6: Test 2: Sustained fire in bed. Body of elderly male adult in supine position on modern box spring, dressed in cotton sweatshirt and pants and covered with a cotton blanket. Arms at sides, legs straight. Fire ignited in paper under edge of blanket at shoulder

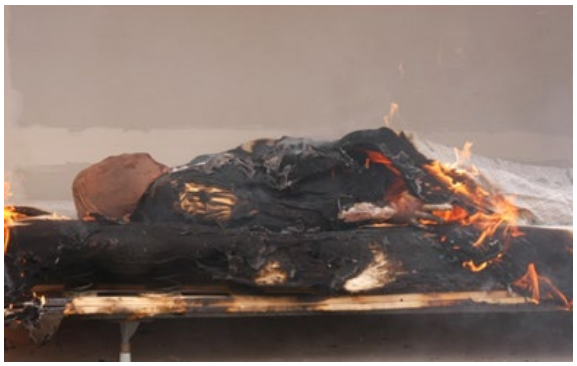

Figure 7: Test 2: At 1hr:16min, the modest fire in the box spring and blanket are causing the fingers of the right hand to flex downward (towards the heat)

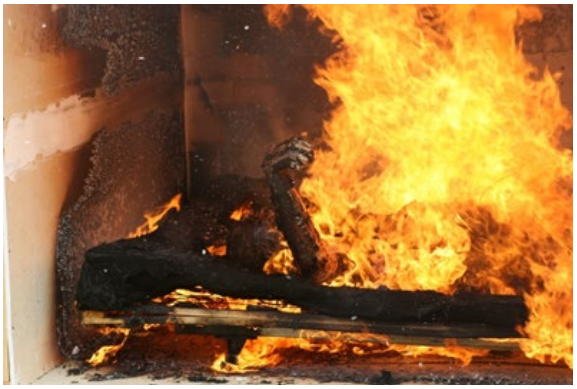

Figure 8: Test 2: At 1hr:55min, there is a substantial fire in the box spring and a pool fire supported by the body fat that has rendered out and gathered on the gypsum wallboard floor covering beneath the torso. Fingers clenched but intact, arm is raised from the shoulder and elbow

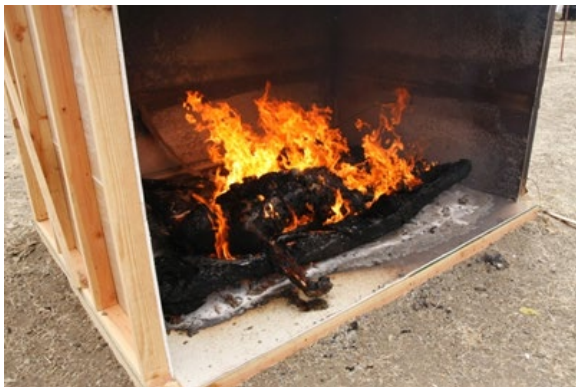

Figure 9: Test 2: At 2hrs:15min, the fire is localized on the body and the pool fire beneath it. The right arm has collapsed outward

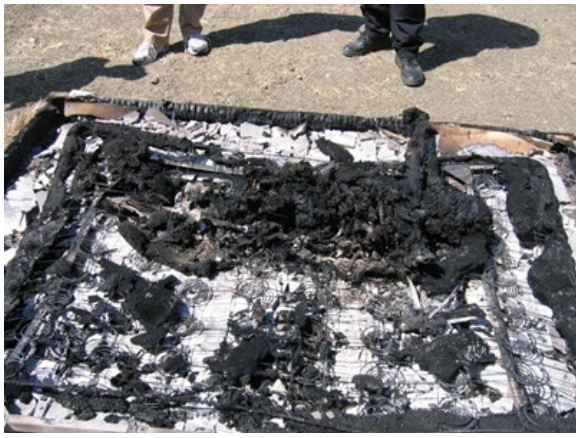

Figure 10: Test 2: After self-extinguishment at 6hrs:15min, the full extent of repositioning can be seen. The left arm is extended out at right angle from the body and the bones heavily calcined and fragmented. The right arm extended out away from the body and is still relatively intact. The knees are flexed outward (legs in a plie ballet position)

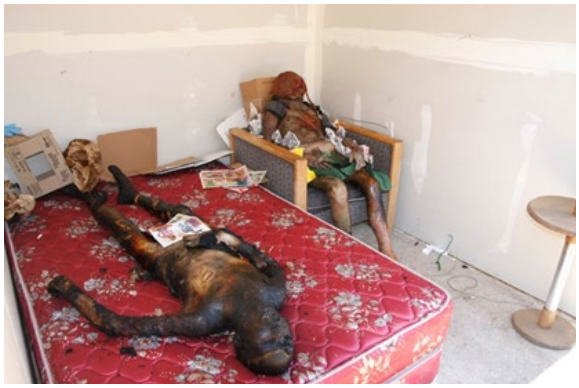

Figure 11: Test 3: Open cubicle fire with two bodies. One body (previously exposed to a low intensity fire) on bed, other slumped in chair. Fire started in paper trash between body and chair. Fire went to flashover at about 7min, post-flashover burning for 13 more minutes (total fire duration was 20 min.)

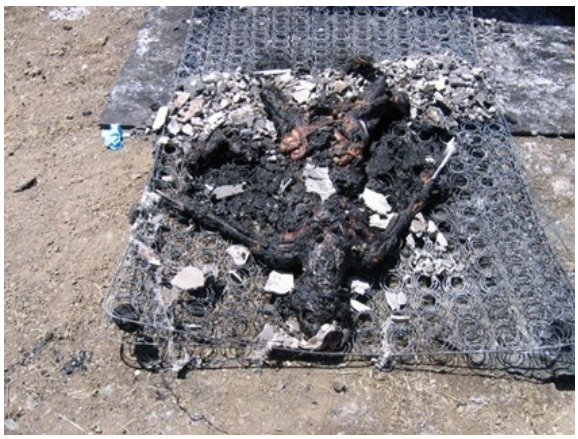

Figure 12: Test 3: Body on mattress displays extensive destruction of soft tissue on arms (hands disarticulated), head tilted back, and arms and legs in different positions than at start of the fire

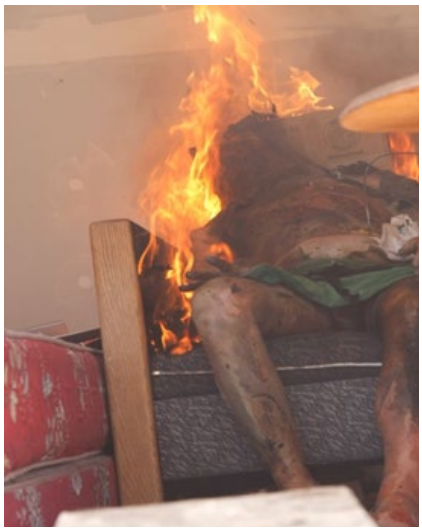

Figure 13: Test 3: At 6min, the fingers of the right hand are splayed outward and the body is twisting to the right. The torso is moving towards the fire as muscles shrink from heat exposure

Figure 14: Test 3: Radiant heat during flashover has caused significant loss of soft tissue from the front of the torso, arms, and legs. Head tilted back (due to shrinkage of muscles at back of neck.) Legs spread apart

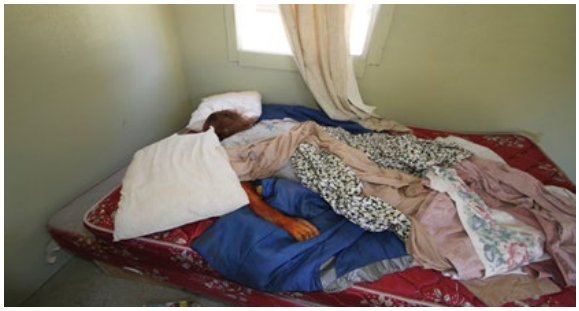

Figure 15: Test 4: Bed fire. Adult male body in supine position with legs straight and arms slightly extended. Fire started on bed. Total duration: 13min (including flashover)

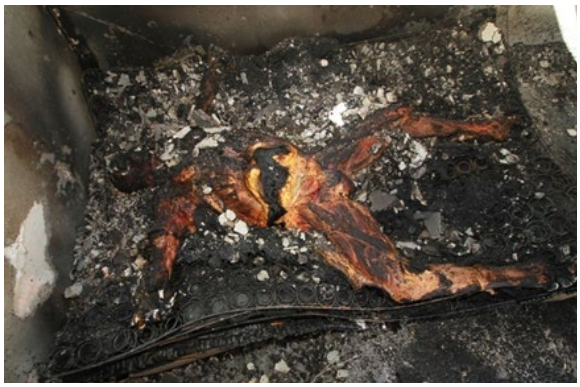

Figure 16: Test 4: Post-flashover: right arm extended out from shoulder. Legs spread. Right leg is nearly off bed. Collapse of bedsprings is aiding movement towards edge

Figure 17: Test 5: Airplane crash (into adjoining room). Body on bed ignited by fire extending from crash. One arm at side, right arm across chest, legs skewed

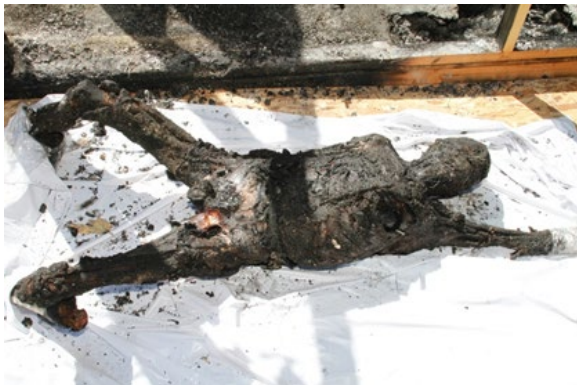

Figure 18: Test 5: After 15.5min fire in room, left arm is extended above head, right arm is by side. Lower legs bent at knees, lower extremities disarticulated

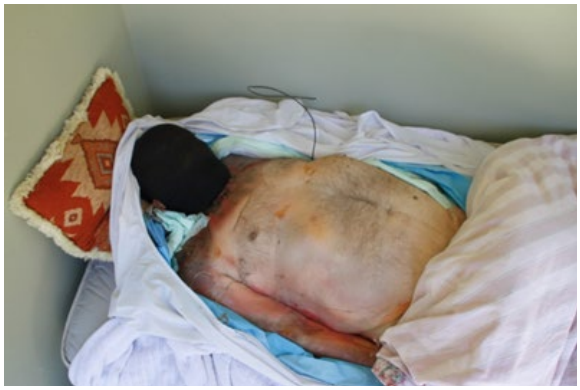

Figure 19: Test 6A: Open cubicle – two bodies – one on bed inside cubicle, one in recliner outside facing fire. Body of nude adult male in supine position, legs extended, arms at sides

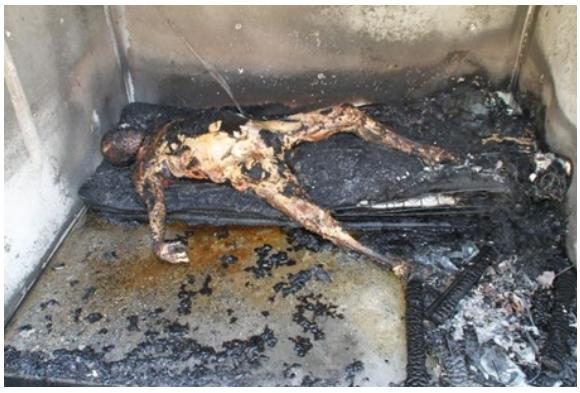

Figure 20: Test 6A: 15min. Subcutaneous fat exposed on torso and legs. Right arm extended out over edge of bed from shoulder. Right leg extended out over edge of bed. Left leg bent at knee. Intense fire on bed but did not proceed to flashover (carpet and wall still intact). Mattress collapse aiding movement towards edge

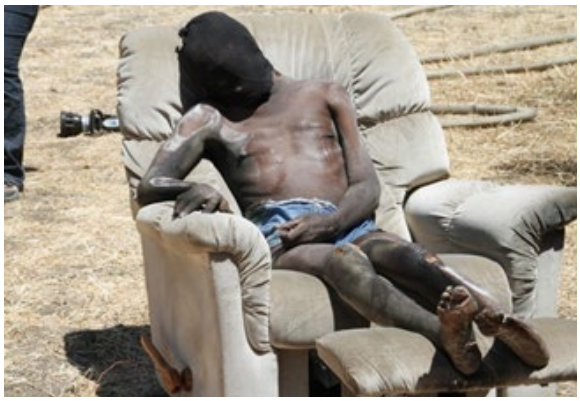

Figure 21: Test 6B: Body in recliner. Starting position

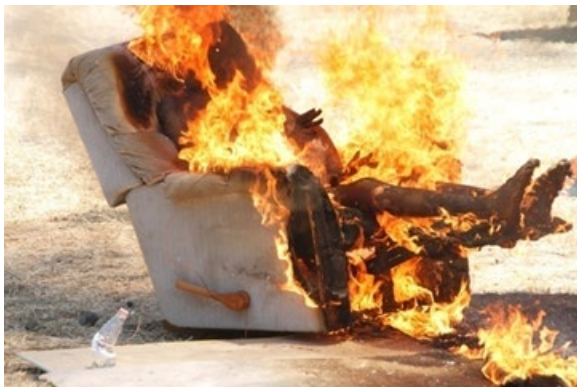

Figure 22: Test 6B: Fire on recliner ignited at 8min by radiant heat from cubicle fire. Hands and forearms raised and fingers splayed. Head turning towards fire, feet curling towards fire as tendons and muscles in sole shrink from heat

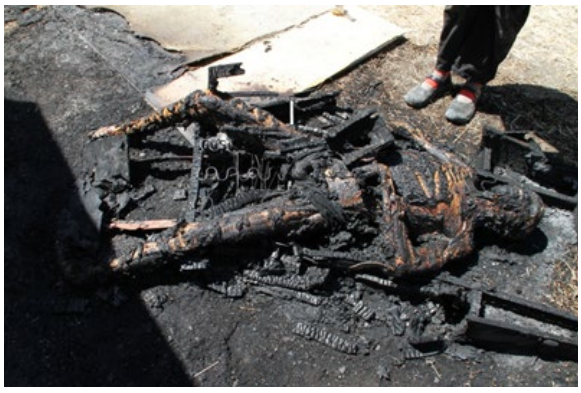

Figure 23: Test 6B: After fire, left arm crossed across body, legs splayed, feet disarticulated. Position of body changed by collapse of chair beneath

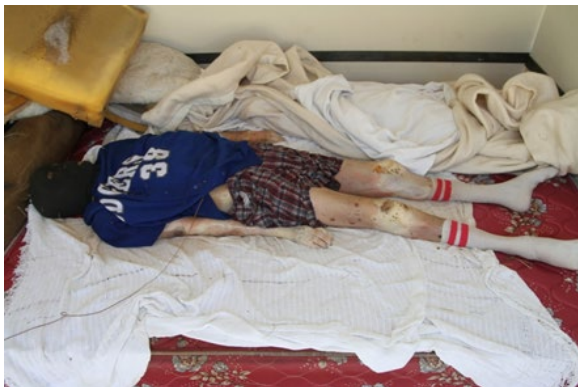

Figure 24: Test 7: Furnished cubicle – body in bed. Adult body on bed, supine position, legs straight, arms at sides

Figure 25: Test 7: 24min including post-flashover. Both arms extended well away from body and straightened. Legs spread but straight. Feet disarticulated

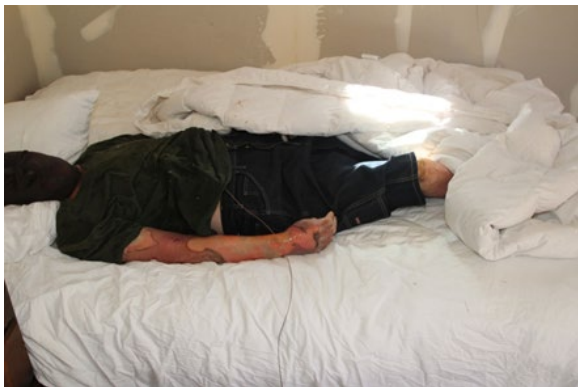

Figure 26: Test 8: Furnished cubicle. Bedroom fire (accelerated with gasoline on bed): murder- suicide. Test 8A: Adult male on bed, dressed and covered with comforter, arms and legs straight (skin slippage from minor post-mortem decomposition). Gunshot wounds to torso

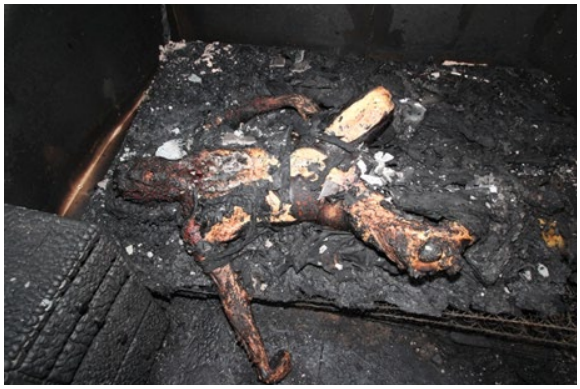

Figure 27: Test 8A: Duration 7.5min (3.5min post-flashover). Right arm extended out over edge of bed, right leg moved towards edge, both legs spread and flexed at knees

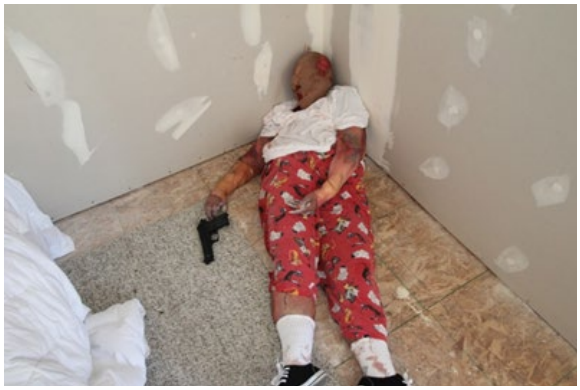

Figure 28: Test 8B: Same cubicle – female assailant (clothed). Gunshot wound to head. Initial position

Figure 29: Test 8B: Corner of room ignited by flashover at 4min. Head and upper torso protected by corner position. Subcutaneous fat exposed on legs. Arms repositioned towards walls, legs spread

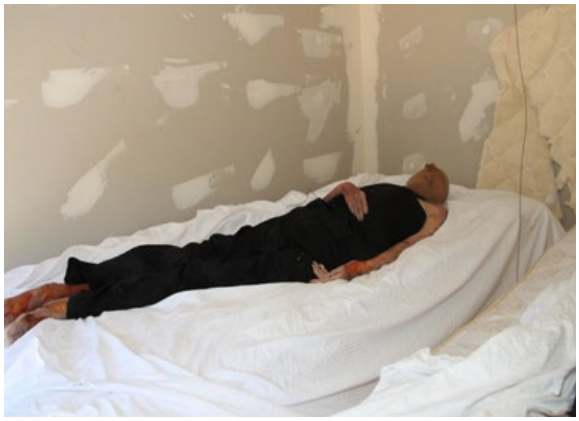

Figure 30: Test 9: Open cubicle – body on bed. Clothed, adult female body on top bunk. Ignition by open flame to bedclothes. Flashover within 1min

Figure 31: Test 9: Both legs flexed, both arms extended from shoulders and flexed. Neck arched back

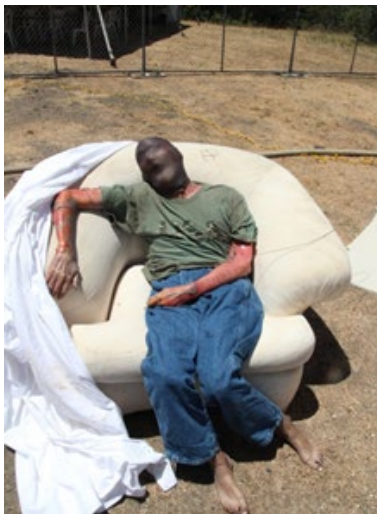

Figure 32: Test 10: Body in recliner. Initial position: adult male, clothed

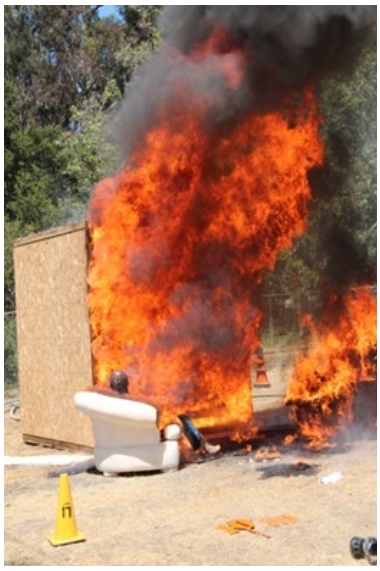

Figure 33: Test 10: Fire ignited on recliner by radiant heat from cubicle flashover fire at 1min. Head and arm rising and head turning towards the fire

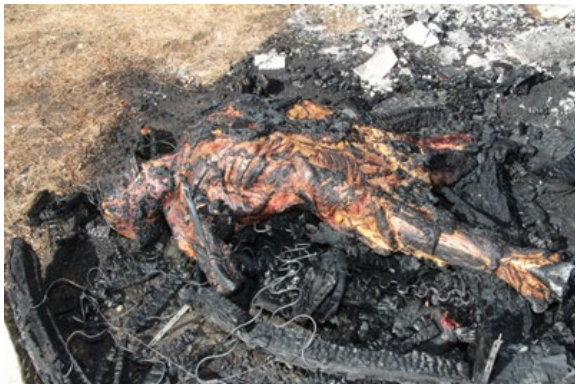

Figure 34: Test 10: Duration of recliner fire: 8min. Both legs and arms extended. Neck arched back. Mouth open

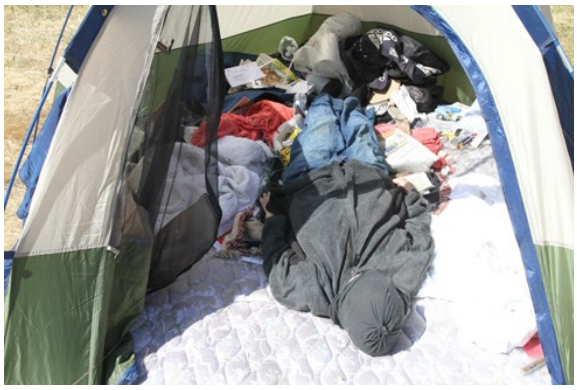

Figure 35: Test 11: Tent fire. Adult female body clothed in sweatshirt and pants supine on a spring mattress. Ignition by cigarette on cotton bedding (at feet). Arms at sides, legs straight and together. Duration of flaming fire 20min

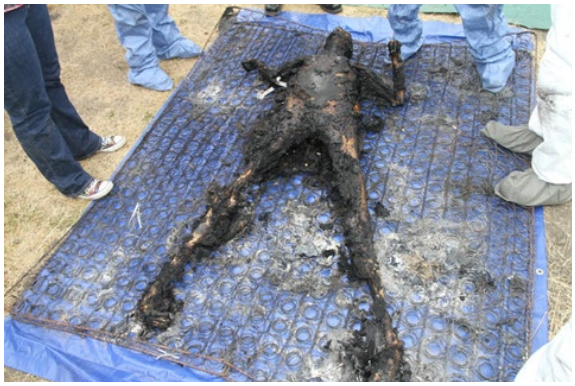

Figure 36: Test 11: After removal of tent and debris, body was left on inner spring mattress for removal. Arms flexed and rose. Legs straight but spread. Lower legs more badly damaged due to longer duration of fire in adjacent normal combustibles

Figure 37: Test 12: This adult male body was in a supine position on the innerspring mattress during a demonstration fire in a furnished cubicle. During the fire, the mattress collapsed and the body ended up in a supine position on the floor adjacent to the bed

Conclusions:

Pugilistic posturing in deceased bodies is the combined result of shrinkage and loss of connective tissues (muscles, tendons, and ligaments) at joints resulting from the thermal effects of heat and fire, not from ante-mortem actions of the victim. It can be extensive or very limited depending on the position of the body and the distribution of the heat applied. Flexion is dominated by shrinkage on the side facing the fire or radiant heat source. Hands and bare feet curl; wrists, hips, knees and ankles flex. Heads turn and necks arch. Such flexion may indicate the direction of fire spread if the fire is not prolonged. Limbs can rise, flex, and straighten during the fire, sometimes sequentially.

Flexion of small joints with thin tissue coverings (fingers and wrists) can begin within five minutes of intense heat exposure. The thicker the protective layer of soft tissues, the longer the delay will be. Significant flexion can move entire limbs. If the movement of arms and legs is sufficient and is accompanied by collapse of chair upholstery or bedsprings, the body may be found in a very different position than it was when the fire began. Investigators must be aware of such movement before concluding the victim was responding voluntarily to the fire.

Restraints such as ligatures or limbs being trapped under the torso or furniture will prevent "normal" movement in response to heat attack. Collapse of supporting furniture can alter the positions of limbs and entire bodies. Destruction of the tissues (soft and bony) follows a predictable sequence and is dependent on the intensity and duration of exposure to heat. As observed in these tests, significant destruction can occur to adult human bodies in a very short time (less than 15min), particularly if the fire is in post-flashover stage involving modern furnishings (with synthetic fabrics and fillers).

Accelerants such as petrol or similar flammable liquids alone have no effect on thermal responses as their duration of their flames is almost always too short to allow penetration of their heat into soft tissues, and their open-flame temperatures are about the same (750-900C) as a well-ventilated room fire in ordinary combustibles. The thicker tissue depths and shorter limbs of adult pigs allow much less response to the same fire insult than observed in human bodies. Investigators must be very cautious about interpreting effects when using pig carcasses in fire tests.

Post-fire remains are very fragile. ANY movement is likely to fracture charred muscle tissue or calcined bone. Bodies must be thoroughly photographed as found, during recovery, and during post-mortem examination. Rigid flat support under the entire body is most desirable. Body-bag recoveries are very destructive, fracturing charred tissue and calcined bones and should be avoided. Careful examination and sifting of the entire area around the body (extending out an arm's length in all directions) is often needed to recover all bones and bone fragments as they can be lost as the body continues to move from fire exposure. Lack of observational data on bodies in real-world fires has led to many misinterpretations. Awareness of these behaviors will reduce errors in the reconstruction of fatal fires of all types.

Table 1: Summary of Tests Represented in the Study

Test 1: Sustained fire on bed in small cubicle. Body of elderly male adult, dressed in cotton sweat shirt and pants on modern box spring, covered with cotton blanket. Body in supine position with legs extended straight and arms by sides. Fire ignited with open flame to paper at edge of blanket. Brief flashover fire. Fire duration was 7 hrs (self-extinguished).
Test 2: Sustained fire on bed in small cubicle. Body of elderly male adult in supine position on modern box spring, dressed in cotton sweatshirt and pants and covered with a cotton blanket. Arms at sides, legs straight. Fire ignited in paper under edge of blanket at shoulder. Brief flashover fire. Fire duration was 6.25 hrs (self-extinguished).
Test 3: Open (three-sided) cubicle fire with two bodies. One body (previously exposed to a low intensity fire) on bed, other slumped in chair. Fire started in paper trash between body and chair. Fire went to flashover at about 7min, post-flashover burning for 13 more minutes (total fire duration was 20 min).
Test 4: Bed fire in furnished cubicle. Adult male body in supine position with legs straight and arms slightly extended. Fire started on bed. Total duration: 13min (including flashover).
Test 5: Airplane crash (into adjoining room). Body on bed ignited by fire extending from crash. One arm at side, right arm across chest, legs skewed. Fire duration in room: 15.5 min
Test 6: Open (3-sided) cubicle – two bodies – one on bed inside cubicle, one in recliner chair outside facing fire. Body of nude adult male on bed in supine position, legs extended arms at sides. Second body seated in recliner. Duration of cubicle fire: 15min.
Test 7: Furnished cubicle – body in bed. Clothed, adult body on bed, supine position, legs straight, arms at sides. Duration 24 min including flashover.
Test 8: Furnished cubicle. Bedroom fire (accelerated with gasoline on bed): murder- suicide.
Test 8A: Adult male on bed, dressed and covered with comforter, arms and legs straight (skin slippage from minor post-mortem decomposition). Gunshot wounds to torso.
Test 8B: Clothed female body slumped in corner with gunshot wound to the head. Total duration: 7.5min, 3.5min post-flashover.
Test 9: Open cubicle with bunk bed. Clothed, adult female body on top bunk. Ignition by open flame to bedclothes. Flashover within 1min. Total duration: 9min.
Test 10: Open cubicle with latex foam mattresses. Body supine in bed. Fire ignited by open flame. Flashover within 1 min. Second clothed adult male body seated in recliner facing the fire. Recliner ignited by radiant heat from cubicle fire. Total duration: 7min.
Test 11: Tent fire. Adult female body clothed in sweatshirt and pants, supine on innerspring mattress. Blankets, clothes, and towels on mattress in a plastic camping tent. Ignition was by cigarette on cotton bedding (at feet). Arms at sides, legs straight and together. Duration of flaming fire: 20min, with rapid consumption of tent material.
Test 12: Open furnished cubicle. Adult male body, clothed, in supine position on innerspring mattress on improvised wood support. Ignition by open flame to combustibles. Duration of fire: approximately 12 min with sustained flashover. The wood support and mattress collapsed during the fire. After the fire, the body was found in supine position on floor, adjacent to the bed.

Highlights:

Heat causes shrinkage of connective tissues that reposition limbs, torsos, and heads
The final position results from all heat effects, not ante-mortem actions
Intense fires, even of short duration, can cause repositioning
Bodies can move even to the point of falling from chairs and beds
Shrinkage of muscles cannot break healthy intact bones
Flexion is dominated by shrinkage on the side facing the fire or radiant heat source

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