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PRIMER

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Collaborative fire research program using donated human remains

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Abstract

Beginning in 2020, Western Carolina University (WCU)'s Forensic Anthropology Program began a research partnership with the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) Fire Programs and Training Branch on burned human remains via a continuing education (CE) course. This course has evolved since its original inception to include a controlled burn utilizing donated human remains. The content of the CE course is primarily geared toward law enforcement, fire investigators, medicolegal investigators, and crime scene technicians. The 2021 course was the first to utilize a donor from WCU's Body Donation Program, a willed-body program where donors or their next-of-kin can provide additional consent for skeletal modification and/or genetics studies. In addition to the educational purposes of running a controlled burn within a flashover cell, small research projects are also being conducted. Bullets were inserted into the 2021 donor to test various detection methods for utility within fire investigations. For the 2022 course, WCU's Forensic Science Program joined this partnership; they inserted seminal fluid into bodily cavities to examine the recovery of genetic material from a secondary contributor after a high-intensity, low-duration fire. The preservation of sharp force trauma in soft tissues was also examined during this course. Genetic material recovery was retested in the 2023 course, as well as examinations of cranial blunt force trauma and blood preservation within a scene. These courses are generating a sample of thermally altered human remains for

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future research and education, in addition to providing insights useful for fire investigators.

This article is categorized under:
Forensic Anthropology > Trauma Analysis
Forensic Anthropology > Taphonomic Changes and the Environment

KEYWORDS
DNA, fire research, forensic anthropology

1 | INTRODUCTION

The Willed-Body Donation Program at Western Carolina University (WCU) began in 2005 and accepted its first donor in 2008. The Willed-Body Donation Program was created in support of a larger initiative at WCU to develop the Forensic Anthropology (FANT) Program. Its creation has encouraged the growth of various laboratories and skeletal collections, including the Forensic Osteology Research Station (FOREST), the world's second-oldest human decomposition facility, the Western Carolina Human Identification Laboratory (WCHIL), and the John A. Williams Human Skeletal Collection (JAW Collection), where willed-body donors are utilized for teaching and research (see George et al., 2022 for additional discussion). Through the donor consent process, willed-body donors or their next-of-kin can provide additional consent for intentional skeletal modification and/or the collection of genetic samples. These additional consents permit intentional destructive analyses for training or research, as well as collaborative opportunities with both internal and external parties.

The goals of this paper are to (1) present an ongoing example of an external partnership between the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) Fire Programs and Training Branch and WCU FANT Program, and to (2) discuss multiple research projects conducted as part of this partnership, the results of which all have implications for scene investigation, data collection, and the interpretation of fire scenes and depict the potential of collaborations such as this. This partnership emerged from a continuing education course in forensic anthropology and burned human remains in 2019, when author D.A.S. contacted author N.V.P. about the feasibility of teaching a course that would bring together the expertise and experiences of forensic anthropologists to train fire investigators on ways to handle scenes with burned human remains in Cullowhee, NC at FOREST. These conversations led to an in-person, 2-day course at WCU in 2020 aiming to provide information that investigators could add to their institutional protocols when encountering burned remains. Fifteen fire investigators from local, state, and federal agencies were enrolled. This first course was primarily lecture-based, with topics ranging from human and non-human osteology, anthropological approaches to burned remains, and case studies. Additionally, there were hands-on components of the course that permitted registrants to handle human and non-human skeletal remains and tour the laboratory facilities at WCU.

Following the 2020 course, arrangements were made to expand the content of the continuing education (CE) course to include a live, controlled burn of a consenting willed-body donor inside of a flashover cell. This updated course content allows WCU forensic anthropologists to educate stakeholders such as law enforcement officials, fire investigators, medicolegal investigators, and crime scene technicians how to view scenes with burned human remains through a forensic anthropological lens. It also provides for the generation of burned body research and evidence collection from these types of scenes in a controlled environment, with the multiple iterations and permutations conducted thus far summarized here.

2 | 2021 CONTINUING EDUCATION COURSE

WCU's 2021 CE course was the first to expand upon the success of the 2020 course with a controlled burn utilizing a donor from WCU's Willed-Body Donation Program. All controlled burns to date at WCU have utilized a flashover cell. A flashover cell is a three-walled structure that permits viewing of events within the cell as it burns, essentially, a room with one wall missing to allow for viewing. This flashover cell was constructed within the larger of the FOREST's two enclosures and arranged like a bedroom, complete with a bedside table, dresser, and bed that the donor was laid on in

FIGURE 1 The donor for the May 2021 burn is shown pre-burn on top of the bedding within the flashover cell.

a supine position. The donor was placed on top of the bedding and dressed in clothing prior to the burn to simulate a real-life scenario while also permitting observation of the body during the burn (Figure 1).

The controlled burn was started using an open flame in a trash can that was filled with lightweight combustibles in the southwest corner of the flashover cell. No accelerants were utilized. This setup within the cell was to simulate a corner configuration started by discarded smoking materials placed in a trash can filled with available combustible materials. The fire quickly spread up the walls of the room and migrated to the furnishings until the room transitioned through flashover and entered a decay phase. Flashover occurs when all the remaining combustible materials within the compartment auto-ignite from the thermal energy present. The fire was extinguished with water by the local fire department after approximately 7 min. Based on the thermocouple data, the highest temperature was almost 1400 degrees Celsius within the flashover cell at around the 4- and 5-min marks after ignition of the fire. Cameras were also arranged within and external to the flashover cell to capture the donor's physical changes during the fire. These permitted observation of the donor into the pugilistic posture; between the 2.5 and 3.5 min marks of the fire, all the donor's limbs had begun transitioning into this "boxer-like" pose (Christensen et al., 2019, p. 440). The original position of the donor can be seen in Figure 1, with the final positionality shown in Figure 2.

Approximately 2 days after the burn, the donor was moved to the smaller surface enclosure at FOREST following the completion of the CE course to permit natural soft tissue decomposition. Undergraduates enrolled in WCU's Forensic Archaeology course later recovered the donor in the fall of 2021 as part of their culminating course activities.

2.1 | Bullet detection methods

For this burn exercise, a simple research project was performed focusing on non-intrusive methods of detecting ballistic projectiles of various common calibers within burned human remains. Three methods of examination were identified based on the criteria of availability, cost, and accuracy. The chosen methods were electromagnetic detection, thermal imaging, and x-ray scanning. The corresponding apparatuses selected to test each method were a handheld magnetometer, a thermal imaging camera, and a portable bomb x-ray unit. After making small incisions, seven bullets of varying calibers were inserted at differing depths throughout the donor's remains to test the efficacy of these detection methods. The donor's remains were scanned both prior to and after the burn to assess their ability to detect the bullets' locations. Of the detection methods used, the handheld magnetometer was the most successful at locating the projectiles after the burn, resulting in locating five of the six bullets that remained in the donor; one bullet had dislodged from the remains due to fire damage. This determination was based on accuracy, ease of use, and logistical considerations experienced with each scanning apparatus.

FIGURE 2 Post-burn, the donor has transitioned into the pugilistic position; this is denoted by the head rotated toward the fire's origin, curved hands, splayed legs, and angled feet.

3 | 2022 CONTINUING EDUCATION COURSE

Both attendees and instructors from the 2021 course deemed the class an overwhelming success, primarily due to the addition of a controlled burn with a donor. This feedback led stakeholders with both the ATF and WCU's FANT Program to think bigger for the next course iteration to continually build upon its potential for both research and teaching. One of the major questions that arose during discussions was regarding the survivability of genetic material, mainly exogenous DNA. Crime concealment is one of the most common reasons for an arson, as arsonists believe that fire will destroy forensic evidence, such as assailant DNA left at crimes such as sexual assaults. These conversations grew to include members of WCU's Forensic Science Program to explore the feasibility of testing the ability to recover exogenous genetic material post-burn for the 2022 CE course. Another question that was discussed was the ability to detect sharp trauma in the soft and hard tissues of human remains following a fire.

The May 2022 CE course again featured a willed-body donor to explore these research avenues. The flashover cell, fire, and donor position were similarly replicated from the 2021 CE course to compare results of body movement and temperature changes, though the fire was permitted to burn for just one additional minute, for a total of an 8-min burn. Technical difficulties prevented the thermocouple data from being collected during the burn.

Following completion of the 2022 CE course, students enrolled in the summer forensic anthropology facilities internship aided in moving the donor into the surface enclosure at FOREST. These students helped to document the decomposition process of this donor, and subsequently, undergraduate forensic anthropology volunteers aided in the recovery of the donor from FOREST several months later. The differences in thermal patterns on the 2022 donor versus the 2021 donor have already provided valuable comparative data in teaching about the impacts of fire on skeletal remains. For example, the thermal alterations in the 2021 donor were contained to the cranium, mandible, clavicles, dorsal surface of the hands, the distal portion of the posterior aspects of the ulnae and radii, the anterior surface of the tibiae, and the feet (Figure 3). In the 2022 donor, the thermal damage was similarly located, though the cranium had far more extensive damage than the 2021 donor, with the charring and calcination extending further along the parietals (Figure 4). Additionally, the feet were less extensively damaged in the 2022 donor, as the tarsals were severely damaged in the 2021 donor. The greater presence of hand bones in the 2022 donor versus the 2021 donor is likely related to differential scavenging between these two donors as opposed to thermal damage (Figures 3 and 4).

FIGURE 3 The skeletal layout of the 2021 burn donor shows the thermal damage to the cranium, hands, tibiae, and feet; the scale is in dm.

FIGURE 4 The skeletal layout of the 2022 burn donor shows more extensive thermal damage to the cranium as compared to the 2021 donor, but less damage to the feet; the scale is in dm.

3.1 | Genetic material survivability

The examination of genetic material survivability was investigated using purchased human seminal fluid, which was pipetted into the mouth, vagina, anus, and around the perineum prior to the controlled burn. Following the burn, external and internal surfaces of these areas were swabbed to detect any remaining exogenous genetic material. Standard methods were used to develop a genetic profile from each swab. All swabs yielded a high-quality, full profile concordant with the donor of the seminal fluid, indicating that this material can survive in a high-intensity, low-duration fire. Results of this project were presented at the 2022 International Symposium on Human Identification (Bintz et al., 2022).

3.2 | Sharp trauma survivability

The examination of sharp trauma post-burn was also investigated in 2022 by creating four knife stab wounds to the donor's thorax during preparation for the controlled burn. These four wounds were measured and documented photographically prior to the fire; two were inflicted on each side of the ribcage, with wounds being placed in the intercostal spaces to maximize the need for soft tissue observation of the trauma. Following the burn, the photographs were

FIGURE 5 The only visible post-burn knife wound on the donor was on the right side of the donor's thorax and is denoted by the red oval.

referred to on the donor's thorax to identify the location of the knife wounds. Even using the pre-burn photographs, only one of the four wounds could be readily identified in the soft tissue (Figure 5); the other three were masked by the postmortem damage to the skin and soft tissues from the burn. Following soft tissue decomposition and subsequent processing of the donor's remains, left rib seven exhibited a sharp trauma defect; this was the only sharp trauma identified on the donor's skeletal remains and does not align with the visible wound in the soft tissue post-burn.

4 | 2023 CE COURSE AND EXPANSIONS

The May 2023 CE course at WCU's facilities built upon the successes and experiences of past classes. The flashover cell and fire were replicated similarly to the 2021 and 2022 CE courses to compare the results of temperature change and subsequent donor movement to one another. However, the fire was permitted to burn for 12 min in this course, which was a 4-min extension upon the previous year. The highest temperature inside the cell was just over 1100 degrees Celsius and was reached just before the 4.5-min mark. As in the previous two CE courses, the donor had been clothed and laid on the bed in a supine position, but with the addition of thermocouples placed in and around various locations throughout the remains; thermocouples were sewn into the oral and anal cavities and safety pinned into the bedding near the right foot, the left hip, both shoulders, and superior to the head.

The May 2023 donor was moved to the surface enclosure of FOREST by CE course attendees on the last day of the course. Like the 2022 donor, the decomposition of this donor was documented by students enrolled in the summer forensic anthropology facilities internship. This donor was recovered with the assistance of undergraduate volunteers in September 2023 and was processed shortly afterwards for curation. The additional comparisons based on thermal patterning alone on this donor can add to those from previous courses will be invaluable to students enrolled in WCU's FANT Program and those in future CE courses.

4.1 | Genetic material survivability

The survivability of exogenous human genetic material was again tested in this course iteration with hopes of replicating the success from the 2022 burn; the same methodology was followed from the previous year, with purchased seminal fluid being pipetted into the oral and anal cavities. The oral cavity produced similar results to the 2022 course, yielding a high-quality, full genetic profile concordant with the donor of the seminal fluid. However, there were some complicating factors in recovering the exogenous genetic material from the anal orifice, likely from the duration of the fire and close contact of these areas to burning material within the flashover cell. Results of this research were presented at the 2023 International Symposium on Human Identification (Bintz et al., 2023).

4.2 | Blood survivability

One of the projects that was added for this burn was examining the survivability of human blood post-burn. A pint of purchased blood was spread on the western wall of the flashover cell, the carpet and bedspread on the western side of the cell, and the bedside table and carpet on the eastern side of the cell at differing times prior to the fire. The blood had been painted so that various locations were dry, semi-wet, and wet at the time of the fire. The locations of the blood were demarked with screws so it would be easier to locate them post-burn. None of the blood in exposed areas was visible under infrared or to the naked eye following the fire. However, one blood stain was visible to the naked eye on the bedspread following the fire; it had been preserved under the donor's remains, protecting it from thermal damage. It was not possible to determine how wet the stain was at the time of the burn given the overall damage to the bedding. The stain was subjected to preliminary DNA testing, but at present, has not yielded any results.

4.3 | Blunt trauma survivability

Blunt trauma was inflicted on the donor to explore its survivability after the fire. A hammer was utilized to inflict one wound to the donor's frontal bone. Following a 2-day cooling period, the cracks across the frontal bone were visible. Additionally, this area of the cranium was subjected to greater delamination during the decomposition process than the rest of the cranium. The comparisons of this donor's traumatic and taphonomic conditions with those from the 2021 and 2022 CE courses demonstrate how a prolonged burn time and inflicted trauma damage skeletal remains in different ways, such as how much damage occurs at traumatic sites as opposed to those undamaged prior to a fire.

4.4 | Accelerant testing

Finally, approximately 2 mL of gasoline was pipetted onto the donor's right pant leg to begin examining the effects of accelerants on soft tissue, skeletal alterations, or any adjacent combustibles, such as clothing or bedding. There was no obvious differential thermal damage to the donor's soft tissue or the combustibles within the flashover cell, including the bedding, due to the gasoline placement. As both femora have similar thermal alterations restricted to their distal ends, the gasoline also did not contribute to skeletal damage in this fire.

5 | IMPLICATIONS AND FUTURE DIRECTIONS

The successes of the four CE courses held thus far have created a bright future for this unique research partnership between the WCU FANT Program, the ATF, and the WCU Forensic Science Program. The demand for this course by investigators led to a second iteration being offered in November 2023. This course had nearly 40 attendees, with international registrants for the first time. There are also waitlists for the May and November 2024 courses, as well. These courses will continue to be accompanied by cadaver dog training courses, which have been running concurrent to this course since 2021.

In just a few years, this partnership has already resulted in training nearly 200 investigators across local, state, and federal agencies about the importance of a forensic anthropological lens when examining fatal fire scenes. Additionally, the small-scale research projects incorporated have generated advancements in scene processing and evidence collection. These projects have increased our understanding of how biological materials can survive fires of various temperatures and durations, shown which detection methods are best for locating projectiles within burned remains, demonstrated the difficulty in locating sharp trauma to the soft tissues post-burn, and revealed how skeletal trauma to areas only superficially covered by soft tissues can be affected by burning. Additionally, the known thermally altered skeletal remains are retained indefinitely, creating a collection which will continue to be used to educate students, investigators, and forensic anthropologists about how skeletal remains are affected by fire. The authors have presented about this continuing education course and the results of research projects within them at the American Academy of Forensic Sciences, the Congress for the International Society of Forensic Genetics, the European Meeting of Forensic Archaeology, the International Symposium on Human Identification, the North Carolina Conference of District Attorneys, and at International Association of Arson Investigators conferences in North Carolina, South Carolina, Texas,

Nevada, and New Jersey. The authors continue to educate investigators, scientists, and colleagues on the benefits of partnerships such as this for the advancement of fatal fire investigations. The partnership among the WCU FANT Program, ATF, and WCU Forensic Science Program is expected to continue for the foreseeable future as there is a clear need for the educational and research-based program provided through this unique collaboration of academic and federal resources.

AUTHOR CONTRIBUTIONS

Rebecca L. George: Conceptualization (equal); project administration (equal); writing – original draft (equal); writing – review and editing (equal). **Nicholas V. Passalacqua:** Conceptualization (equal); project administration (equal); writing – original draft (equal); writing – review and editing (equal). **Darren A. Solomon:** Conceptualization (equal); funding acquisition (equal); project administration (equal); resources (equal); writing – review and editing (equal). **David M. Schauble:** Conceptualization (equal); resources (equal). **Brittania J. Bintz:** Conceptualization (equal); data curation (equal); formal analysis (equal); methodology (equal); project administration (equal); resources (equal); writing – review and editing (equal). **Hannah Noel:** Methodology (equal); writing – review and editing (equal).

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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REFERENCES

Bintz, B. J., Noel, H., Solomon, D. A., Schauble, D., George, R., & Passalacqua, N. (2022). *Recovery of high-quality male nuclear DNA from a human female cadaver after exposure to a high-intensity, low-duration fire* [Conference presentation]. International Symposium on Human Identification 2022, Washington, DC.

Bintz, B. J., Noel, H., Solomon, D. A., Schauble, D., George, R., & Passalacqua, N. (2023). *Continuing research to assess the recovery of perpetrator high-quality nuclear DNA from the internal cavities of mock human sexual assault victims exposed to high-intensity, low duration fires* [Conference presentation]. International Symposium on Human Identification 2023, Denver, CO.

Christensen, A. M., Passalacqua, N. V., & Bartelink, E. J. (2019). *Forensic anthropology: Current methods and practice* (2nd ed.). Academic Press.

George, R. L., Zejdlik, K., Messer, D. L., & Passalacqua, N. V. (2022). The John A. Williams human skeletal collection at Western Carolina University. *Forensic Science*, *2*(2), 362–370. https://doi.org/10.3390/forensicsci2020026

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