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Victim identification and body completeness based on last known location at the World Trade Center

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ABSTRACT

This analysis focuses on the identification efforts conducted by the New York City Office of Chief Medical Examiner (NYC OCME) over a 20-year period from September 11, 2001 to September 11, 2021. Due to this unprecedented level of commitment to victim identification, a wealth of data has been collected over the two-decade period and is still being collected as identification efforts are ongoing. The results of this data analysis are not only informative for the World Trade Center (WTC) victims, but may also be instructional for other large-scale, protracted victim identification efforts. Based on available data, most victims are associated with the impact zones and higher in both towers. No correlation was observed in the overall identification rates based on last known location in the buildings, suggesting that location in the towers does not affect the likelihood of a successful identification. There was, however, a significant difference in the body completeness values observed for victims from the upper floors compared to those below the impact zones. The identification rates and body completeness values for victims onboard the two airplanes are significantly different from each other, possibly related to the varying aircraft speeds at the time of impact.

1. Overview of the September 11, 2001 attack on the World Trade Center

On September 11, 2001, both of the 110-story World Trade Center (WTC) towers in New York City were attacked by terrorists. At 8:46 in the morning, the North Tower (WTC 1) was struck by American Airlines Flight 11, which had departed earlier from Boston's Logan International Airport carrying 81 passengers (including five terrorists), two pilots, and nine flight attendants [1,2]. At 9:03 in the morning, the South Tower (WTC 2) was struck by United Airlines Flight 175, which had also departed from Boston's Logan International Airport. It was carrying 56 passengers (including five terrorists), two pilots, and seven flight attendants [1,2]. The South Tower collapsed first at 9:59 and the North Tower collapsed almost 30 min later [2].

The attack on and subsequent collapse of the Twin Towers resulted in one of the largest crime scenes and most complex mass disaster recovery operations in United States history. The debris field created from the collapse of the towers spanned more than 16 acres (65,000 square meters), with a primary debris field 70 feet (21 m) above ground surface and eventual excavation extending approximately 70 feet (21 m) below ground surface. Subterranean fires reportedly burned at high temperatures for several months, further complicating the recovery process [1,3–5]. Excavation at the site, largely managed by the Fire Department of the City of New York, involved heavy equipment and approximately 1.7 million US tons (1.5 million metric tons) of debris being transferred to the Fresh Kills Landfill in Staten Island where controlled search and sifting operations recovered mostly fragmented human remains [1,3,4]. The initial search and recovery operation at the WTC site and Fresh Kills Landfill lasted nearly a year.

The WTC attack should be viewed as a mass fatality disaster involving both open and closed manifests [1,3,4]. United Airlines (UA) Flight 175 and American Airlines (AA) Flight 11 can be considered a closed manifest event, as documented lists of passengers and crew were available. The collapse of the towers, however, is considered an open manifest event since it was initially unknown who was in the towers, who escaped, and who was in the immediate area when the buildings collapsed. Due to the open manifest component of this disaster, it is important to recognize that the total number of victims who died that day may fluctuate slightly as more information becomes available, even after two decades. If someone was killed and was never

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reported missing, they would not be included in the current victim count. Furthermore, due to body fragmentation, burning, and the complex recovery operations, remains may not have been recoverable from all the victims.

All WTC identification statistics are managed by the New York City Office of Chief Medical Examiner (NYC OCME). As of September 11, 2021, there were 2753 known victims and 21,905 remains had been recovered. Identifications had been made for 1647 known victims (59.83 %) and the remaining 1106 were still unidentified (40.17 %). A successful identification means that remains have been positively associated to a known victim. This could range from a small bone fragment to an entire body. From the recovered remains, 14,750 had been associated with a victim while 7155 had not yet been identified despite prior efforts. In many cases there have been multiple fragmentary remains identified to the same victim. The reported values only reflect victims of 9/11 and do not include the terrorists.

2. The role of the New York City Office of Chief Medical Examiner

The NYC OCME had a minimal role in the initial recovery effort that occurred in 2001 and 2002 in lower Manhattan and at the Fresh Kills Landfill. The primary focus during this time was on mortuary operations, and the most essential roles of the NYC OCME in the immediate aftermath of the attack were to provide positive identification of the victims, issue death certificates, and facilitate the repatriation of remains to victims' families [3,5].

During the subsequent reconstruction work that occurred at the WTC site, there were periodic discoveries of additional human remains. As a result, the NYC OCME assumed a lead role in renewed search and recovery efforts at the site which formally lasted from 2006 to 2013. The renewed search and recovery work was initially prompted by the unexpected discovery of human remains on the rooftop of the Deutsche Bank building, located at 130 Liberty Street, directly south of the WTC towers. The 40-story building had to be deconstructed due to significant damage inflicted by debris from the collapse of the WTC towers and, during the deconstruction process, workers periodically discovered fragmentary bones and small pieces of airplane debris on the rooftop. Due to the increased frequency of these discoveries at the Deutsche Bank building, the NYC OCME established an on-site presence starting in April 2006 and performed a systematic recovery operation at the location [4,6]. In total, 783 human bone fragments and associated WTC debris were recovered from the rooftop. Based on subsequent discoveries around the WTC site, the project was greatly expanded and included other rooftops, large construction zones around the site, and hundreds of subterranean structures (e.g., utility manholes) [4,6,7], resulting in the recovery of an additional 1151 fragmentary remains.

In addition to other roles, the NYC OCME has always managed the important responsibility of communicating with WTC families regarding ongoing identification efforts and the final disposition of remains. The NYC OCME follows a formalized notification process whenever remains are identified. Based on family wishes, notifications either occur each time remains are identified to a victim or not at all. For families choosing notification, they have the option to claim the remains through a New York licensed funeral director or keep them in the World Trade Center Repository. The Repository is a NYC OCME facility that is located at the 9/11 Memorial at the World Trade Center site. It includes a Family Reflection Room, which is reserved for WTC families to privately pay their respects, and a secure area next to the Reflection Room where the remains are located. Except for samples undergoing additional DNA testing, all the WTC remains in the custody of the NYC OCME are housed within the Repository. For families who choose not to be notified of new identifications, these remains are also maintained at the Repository. Families can change their notification wishes at any time and can also claim remains at any time, regardless of their original wishes.

3. Methods

The WTC victim list used for this analysis includes individuals who died as a direct result of the impact by the planes and the subsequent collapse of the towers, excluding the terrorists. It does not include responders who may have died due to health complications associated with the protracted search and recovery efforts.

The data for this analysis were collected using two computerized databases, known as "WTC DataEase" and the "OCME WTC Integrated Case Management System." Additionally, every victim and all recovered human remains have their own separate hard-copy case folders. Information compiled for known victims includes identification status, employer, and last known location. Data for employer and last documented location were determined through a review of the NYPD Personal Information Questionnaire Forms that were completed during initial interviews with family, friends, and co-workers and from the New York City Law Department World Trade Center Unit Intake Forms that were completed by next-of-kin.

For victims who have been identified, additional information was collected from the WTC DataEase program regarding the number of remains identified, date(s) of the identification(s), and identification modalities. Data regarding overall body completeness for the 1647 identified victims were also compiled through a documentation review of the written descriptions, medical examiner diagrams, and photographs for all remains associated with each victim. Based on the available information, a comprehensive body diagram was completed to visually estimate overall body completeness. The comprehensive body diagram is a compilation of all remains that have been positively identified to a specific victim. A point estimate was determined based on the diagram and the percentage of body completeness was also categorized into four groups (< 5 %, 5–50 %, 51–95 %, and > 95 %).

4. Identification rates based on last known location

Based on available data pertaining to last known location (Table 1), there are 1510 victims associated with the North Tower (WTC 1), 736 victims associated with the South Tower (WTC 2), 87 victims associated with AA Flight 11 (which impacted the North Tower), and 60 victims associated with UA Flight 175 (which

Table 1
Identification Status by Location as of September 11, 2021.

Location	Total Number of Known Victims	Number/Percentage Identified Victims
WTC 1 and WTC2 (combined)	2246	1322 (58.86 %)
WTC 1	1510	877 (58.08 %)
WTC 2	736	445 (60.46 %)
WTC 1 impact zone (floors 92–100)	454	261 (57.49 %)
WTC 1 impact and above	1336	764 (57.19 %)
WTC 1 below impact (floor 91 and below)	137	86 (62.77 %)
WTC 1 unknown location	37	27 (72.97 %)
WTC 2 impact zone (floors 77–85)	121	63 (52.07 %
WTC 2 impact zone and above	658	390 (59.27 %)
WTC 2 below impact (floor 76 and below)	45	30 (66.67 %)
WTC 2 unknown location	33	25 (75.75 %)
AA and UA (combined)	147	95 (64.63 %)
AA Flt 11	87	67 (77.01 %)
UA Flt 175	60	28 (46.67)
Other (died in hospital, different location surrounding the site, location unknown)	360	230 (63.89 %)

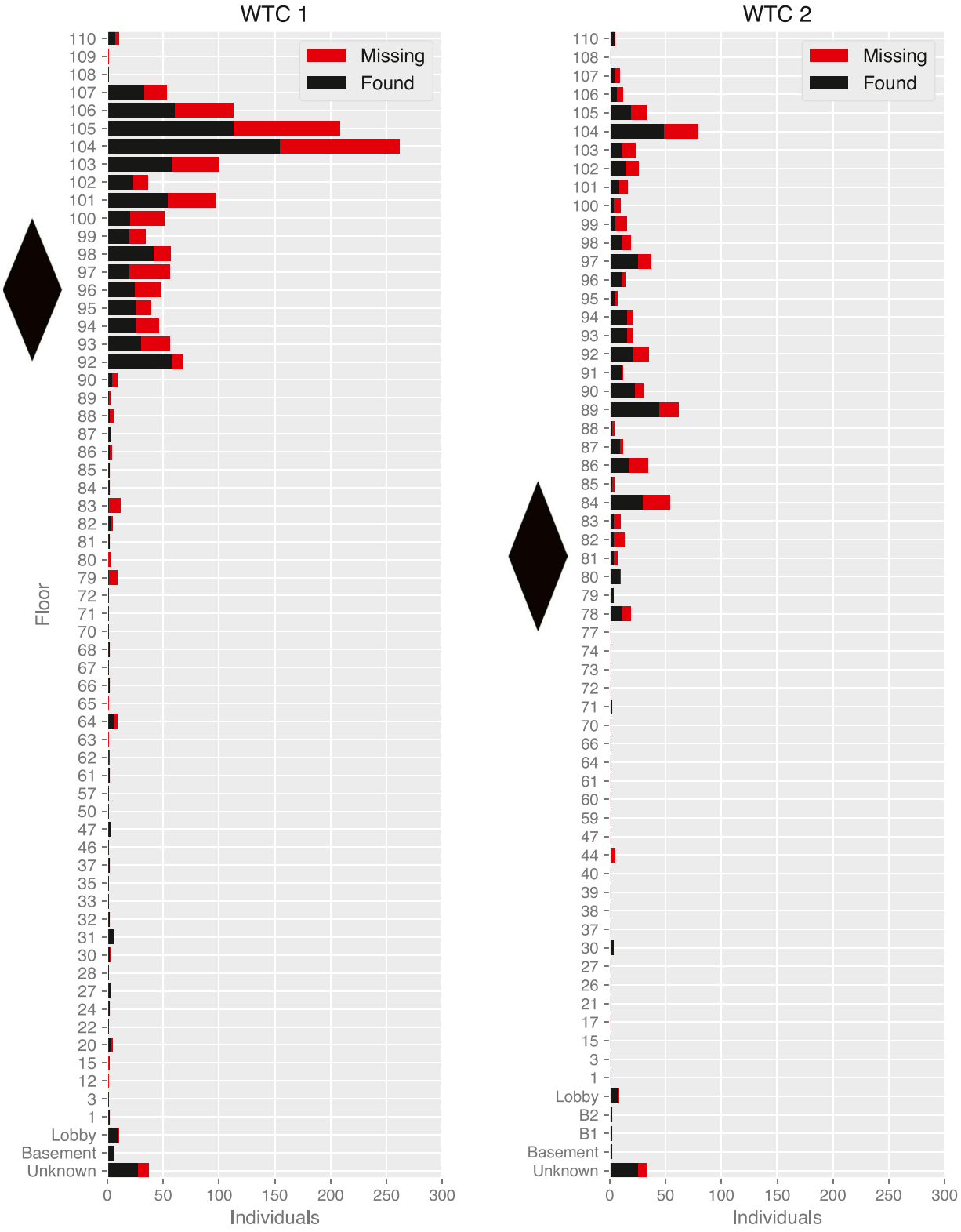

Fig. 1. Diagram based on last known victim locations and identification status. Only floors with at least one associated fatality are shown. Diamonds represent airplane impact zones.

impacted the South Tower). An additional 360 people died at various locations surrounding the WTC site, in hospitals, or their specific location at the site is unknown. These reported values pertain only to the known WTC victims and do not include the terrorists.

4.1. The towers

Without question, people were moving throughout the buildings and the exact locations of many victims cannot be known with certainty. Data regarding last documented location were compiled

for this study from multiple sources, including police investigation documents and correspondence from family members, and, as such, represent the best available information.

Over half of the WTC fatalities are associated with the North Tower which was the first to be struck. Both towers have similar identification success rates (58 % for the North Tower and 60 % for the South Tower). A chi-square test looking at the identification rates of the victims from each tower ($\chi^2(1) = 1.02$, $p = 0.311$) shows that there is not a statistical difference.

According to government reports [2,8], AA Flight 11 struck the North Tower between floors 92–100 and UA Flight 175 struck the South Tower between floors 77–85. The stairwells were reportedly impassable from the 92nd floor and up in the North Tower, while one stairwell reportedly remained passable in the South Tower from at least the 91st floor down and possibly from the top of the building [2,8].

Fig. 1 and Table 1 break down the identification status based on last known locations and their relationship to the impact zones. For the North Tower (WTC 1) there are 1473 victims with a specific floor location reported in the building. Of these individuals, 1336 victims (91 %) have a last known location on floors at or above the impact zone (floor 92 and above). There are 137 victims (9 %) with a documented location below the impact zone (floor 91 and below). For the South Tower (WTC 2) there are 703 victims with a reported location in the building. Of these individuals, 658 victims (94 %) have a last known location on floors at or above the impact zone (floor 77 and above). There are 45 victims (6 %) with a documented location below the impact zone (floor 76 and below).

Fig. 1 shows that the identification success rates for some floors that were directly impacted by the planes is lower than other locations. For example, Floor 97 in the North Tower has a 34 % identification rate and Floors 82 and 83 in the South Tower each have 23 % and 30 % identification rates, respectively. The overall identification rates for the victims associated with the floors below the impact zones (62.77 % and 66.67 % for WTC 1 and 2, respectively) are slightly higher than the overall identification rates for the victims associated with the impact zones and above (57.19 % and 59.27 % for WTC 1 and 2, respectively). However, a chi-square analysis of the overall identification rates of victims associated with the impact zones and above compared with victims associated with floors below the impact zones does not show a statistically significant relationship for either tower. For WTC 1, $\chi^2(1) = 1.33$, $p = 0.246$ and for WTC 2, $\chi^2(1) = 0.675$, $p = 0.411$. As stated above, there is not a statistically significant correlation between last known location and the identification rate in either tower, suggesting that a victim's last documented location in the building does not necessarily influence the likelihood of a successful identification.

4.2. The planes

There is a large difference between the identification success rates associated with the two planes (76 % for AA Flight 11 % and 47 % for UA Flight 175). A chi-square test looking at the identification rates of the airplane victims ($\chi^2(1) = 13.0$, $p < 0.001$) shows that there is a statistical difference between the two.

The increased identification rate of victims associated with AA Flight 11 is partially due to the discovery of 783 small bone fragments discovered on the rooftop of the Deutsche Bank building. DNA testing was successful for 325 of the fragments from the Deutsche Bank roof and all of them were determined to be from victims of AA Flight 11. Potential explanations for how the AA Flight 11 remains ended up on the roof of the Deutsche Bank building are beyond the scope of this paper.

The DNA profiles developed from the Deutsche Bank remains were associated with at least 54 different victims of AA Flight 11.

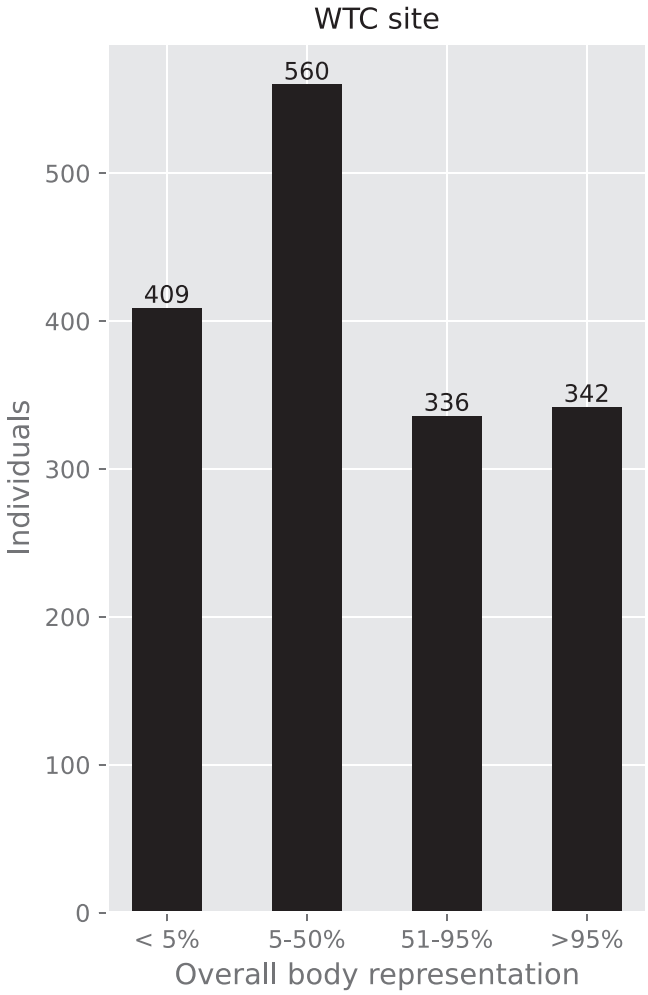

Fig. 2. Body completeness for all identified individuals, regardless of loss location.

There were 6 newly identified individuals (first-time identifications) and 48 individuals who had been previously identified by remains recovered from other locations. Based on these results, a minimum of 62 % of the AA Flight 11 victims had remains recovered from the rooftop of the Deutsche Bank, which is located one block south of the WTC site. The 6 new identifications associated with the Deutsche Bank account for some of the difference seen between AA Flight 11 and UA Flight 175 identification rates but, even without consideration of the Deutsche Bank discovery, the AA Flight 11 identification rate would still be considerably higher than the UA Flight 175 identification rate. UA Flight 175 was reportedly traveling about 100 mph (160 kph) faster than AA Flight 11 at the time of impact [8], which may have contributed to the observed differences in identification rates of the airplane victims.

5. Body completeness

There were extensive traumatic injuries to almost all of the WTC victims. As a result, many individuals were incomplete when recovered and there was often considerable body fragmentation. For this reason, it is very common for a single victim to have multiple remains identified to them and for many victims to have missing portions of their body. Body diagrams were reviewed for the 1647 identified individuals to estimate overall body completeness values.

Fig. 2 shows the percentage of body completeness for all victims regardless of location. The majority of the victims (59 %) have less

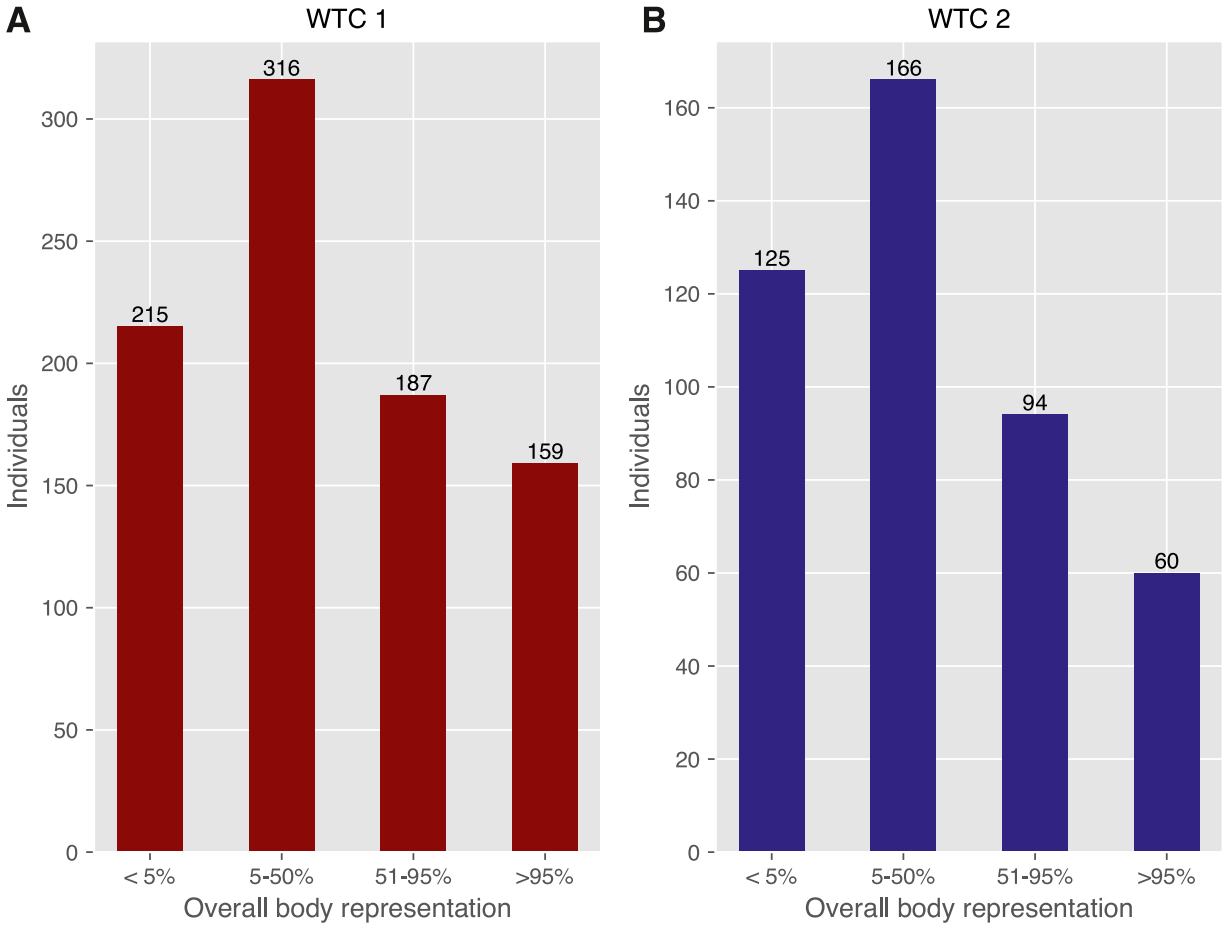

Fig. 3. Body completeness for the North Tower (A) and South Tower (B).

than 50 % of their body represented. Average body completeness for all 1647 of the identified victims is 44 %.

5.1. The towers

Average body completeness for the victims associated with the towers is 41 %. The results show similar body completeness values for both the North and South Towers (Fig. 3). The majority of individuals associated with the towers have less than 50 % body completeness, but in both locations there are also individuals with nearly complete bodies.

Table 2 breaks down body completeness by various site parameters. The body completeness values are extremely similar for both the North and South Towers. Of the 764 identified victims from the North Tower (WTC 1) whose last known location was at the impact zone and above (floors 92 and higher) the average body

Table 2
Body Completeness by Location.

Location	Average Body Completeness	Standard Deviation	Median Body Completeness	Number of Individuals
WTC 1 and WTC 2 (combined)	40.87 %	37.9 %	25 %	1322
WTC 1 impact zone- (floors 92–100)	33.57 %	35.4 %	15 %	261
WTC 1 impact and above	37.33 %	36.53 %	20 %	764
WTC 1 below impact- (floor 91 and below)	76.19 %	32.4 %	95.5 %	86
WTC 2 impact zone (floors 77–85)	37.02 %	35.7 %	20 %	63
WTC 2 impact zone and above	34.01 %	35.6 %	15 %	390
WTC 2 below impact- (floor 76 and below)	81.10 %	18.9 %	87.5 %	30
AA and UA (combined)	9.77 %	14.0 %	3 %	95
AA Flt 11	12.84 %	15.6 %	5 %	67
UA Flt 175	2.43 %	2.88 %	1 %	28

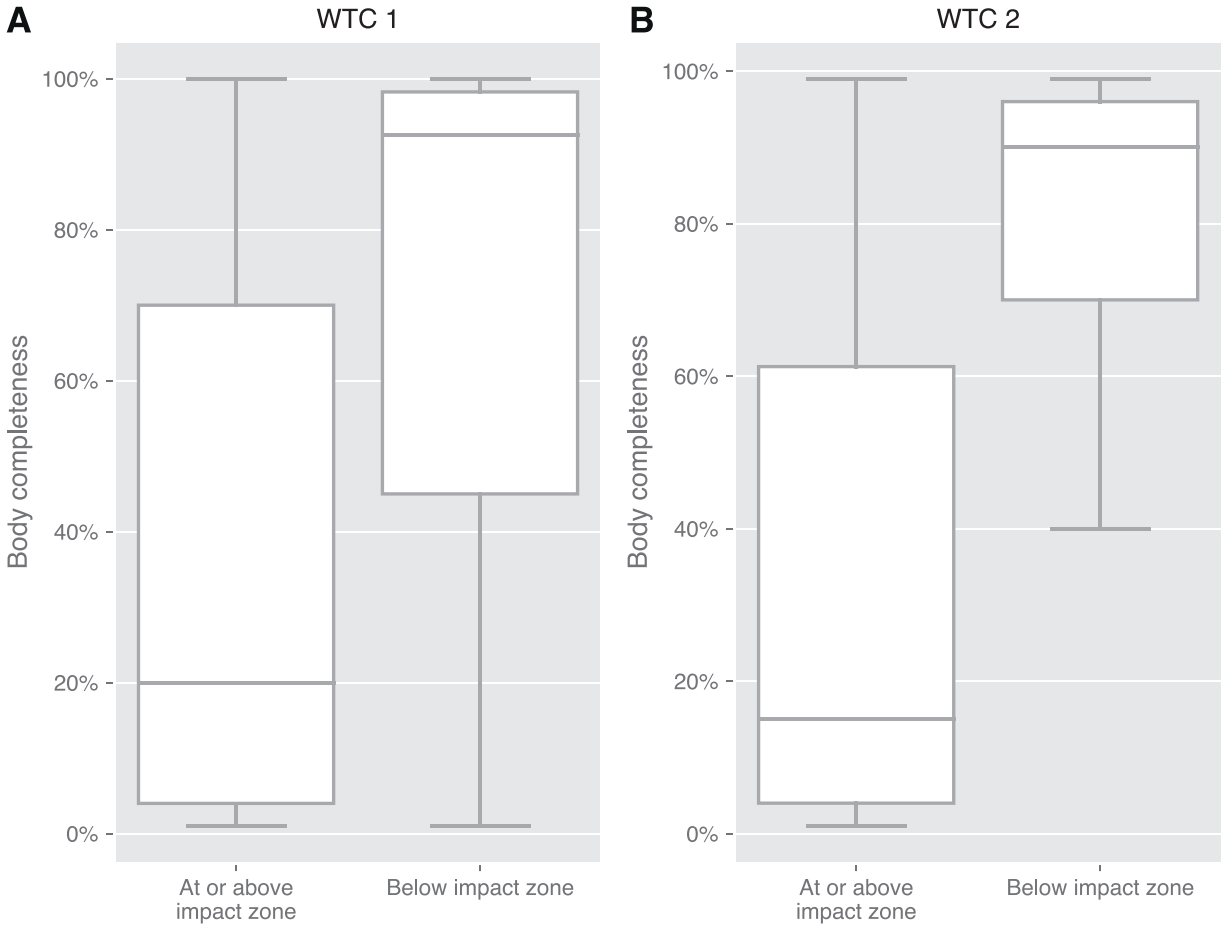

Fig. 4. Body completeness for the North Tower (A) and South Tower (B) based on relationship to impact zones.

completeness is 37 %. Body completeness is significantly higher for individuals associated with floors below the impact zone in the North Tower with an average value of 76 %. For the South Tower, the 390 victims associated with the impact zone and above (floors 77 and above) have an average body completeness of 34 %. The body completeness for the South Tower victims below the impact zone is also significantly higher at 81 %.

An independent-samples t-test was conducted to compare mean body completeness values for victims associated with the impact zones and above compared with victims below the impact zones. For WTC 1, $t(850) = 9.45$, $p < 0.001$ and for WTC 2, $t(420) = 7.17$, $p < 0.001$. Both towers show a statistically significant difference in mean body completeness for victims associated with lower floors and victims associated with floors at and above the impact zones (Fig. 4 and Table 2).

5.2. The planes

As might be expected, the body completeness values for the passengers and crew of both airplanes are very different than the towers. Average body completeness for the victims of the airplanes is 10 %, compared with 41 % for the victims of the towers. For the airplane victims, a high percentage of individuals have less than 5 % body completeness and none of the victims are represented in the > 95 % category (Fig. 5 and Table 2). The lower body completeness values for the airplane victims likely corresponds with increased body fragmentation and decreased recovery of victim remains.

There is a noticeable difference between the body completeness values of the two airplanes. Average body completeness for AA Flight 11 is 13 % and for UA Flight 175 it is 2 %. An independent-samples t-test showed a statistically significant difference between the two planes ($t(95) = -3.48$, $p < 0.001$). The maximum body completeness value for any AA Flight 11 victim was 75 % while the maximum value for any UA Flight 175 victim was 15 %. The difference in body completeness between the planes cannot be attributed to the Deutsche Bank remains since they were all very small bone fragments.

The lower body completeness values associated with UA Flight 175 may explain the lower identification rate of those victims, as discussed above. As noted previously, UA Flight 175 was reportedly traveling about 100 mph (160 kph) faster than AA Flight 11 at the time of impact [8], which may have played a role in the observed differences between body completeness values of the airplane victims.

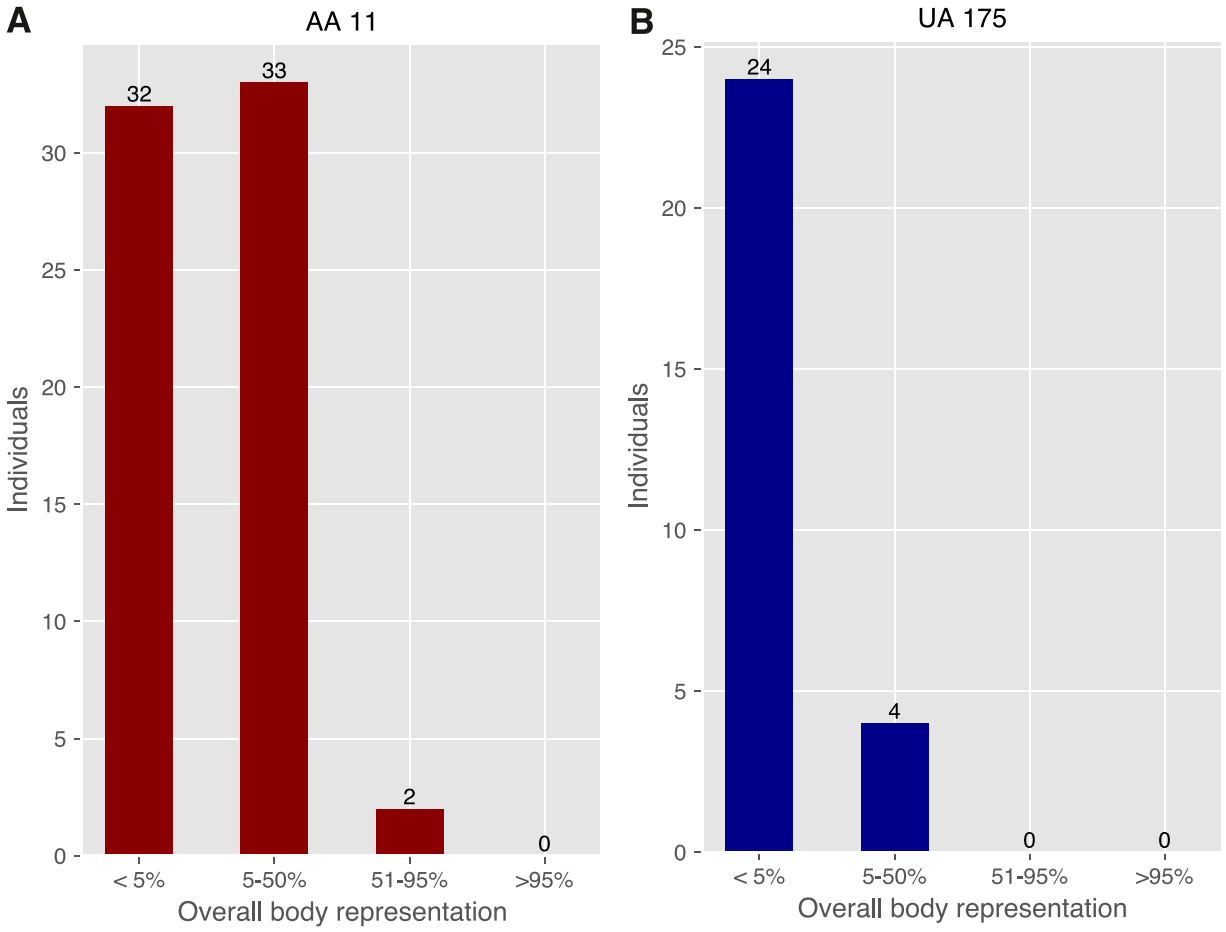

Fig. 5. Body completeness for AA Flight 11 (A) and UA Flight 175 (B).

6. Conclusions

In summary, the WTC data collected by the NYC OCME over a 20-year period provides extremely valuable information about the victim identification process in a large-scale, highly fragmented, and complex mass fatality incident. Although identification success rates are lower on some floors directly associated with the airplane impact sites, it was found that the overall identification success rates in the towers were not correlated with last known location. This indicates that the location in the buildings does not necessarily influence the likelihood of a positive identification.

Body completeness values were very consistent for victims of both towers, depending on their last documented location. Victims associated with the upper floors had lower body completeness values as compared to victims associated with floors below the impact zones. The observed differences in body completeness values based on relationship to the impact zones was found to be statistically significant.

Regarding the two airplanes, the differences in identification rates and body completeness values were statistically significant for victims associated with AA Flight 11 and UA Flight 175. Aircraft speeds at the time of impact could be one possible explanation for the variation seen with identification success rates and body completeness values of the airplane victims.

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Bradley Adams: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing, **Julia Warnke-Sommer**: Formal analysis, Visualization, Writing – original draft, Writing – review & editing, **Jennifer Odien**: Data curation, Writing – original draft, Writing – review & editing. **Angela Soler**: Writing – original draft, Writing – review & editing.

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