# Anatomy and Anthropometry Analysis for Canine Injury and Body Armour Considerations

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**Abstract.** Military and police working dogs work alongside our uniformed service members as integral parts of the team. Much research has been completed on body armour for police and warfighters, but important information is lacking on coverage areas, injury risks, and body armour performance for canines. This study investigates vital thoracic organ anatomy and anthropometry between the human and canine for application with body armour development and coverage areas. Previous studies noted that coverage areas varied widely between different types of canine body armour currently on the market, but no standardised injury assessments were made regarding reduced injury risks with larger coverage areas. For this study, computed tomography scans of the human and canine thorax were obtained and measurements of the heart, lungs, and rib cage were assessed. Similarities and differences between the human and canine were discussed, especially related to body armour coverage areas. While humans need front and back protection to cover the majority of the thoracic vital organs, canines need protection on both sides as well as the front of the thorax. Additionally, the location of the heart within the thorax differs for the canine compared to the human, which is important when considering where to place the most armour protection. Future work includes the development of a standard canine injury scoring system and visualization tool to further enhance body armour coverage and protection for the working dog.

## 1. INTRODUCTION

For years, body armour has been developed to meet a standard of protection against various threats for our uniformed service members. As our understanding of materials and injuries evolve, so too does the armour which has become lighter and better at protecting against emerging threats. Also evolving are the roles and specialised tasks of military and police working dogs, increasing their risk of exposure to the same threats as their handlers. As working dogs are integral members of uniformed services teams, their protection and survivability is intrinsically tied to the survivability of their human team members. It is important to ensure the working dogs have the same level of protection for completing their jobs as their human counterparts. Currently there is a lack of standardised methods specific for canines for the certification and coverage of armour worn by military and police working dogs.

While there are some similarites when comparing the thoracic cavities of a human and canine, the differences are such that the coverage area for armour, injury severity, and injury risk need to be evaluated specifially for canines. The anatomical standing position for the canine is four paws on the ground with the thorax positioned parallel to the ground, where for a human the two feet are on the ground with the thorax perpendicular to the ground. The bony structures of the canine thorax are similar to that of a human and are comprised of rib pairs that form the bilateral limits of the thoracic cavity, sternum comprised of a segmented row of unpaired bones forming the thoracic cavity base, and the vertebral column. Both the canine and human thoracic cavity contain vital organs, including the heart and lungs. The canine's heart is very similar to the human heart and is located between the lungs. The lungs of a canine are not only important for respiration but also aid in regulating body temperature; to decrease body temperature, heavy breathing or panting is necessary. [1,2]

 https://doi.org/10.52202/078352-0004

Developments in personal protective equipment (PPE) have primarily been related to advancements in the study and construction of materials and an increased understanding of the injury risk. With regards to material solutions, innovations designed for service members can also be implemented in PPE for working dogs. However, when it comes to understanding injury risk, the unique anatomy and physiology of canines does not directly translate to the human, necessitating specific research for canines and a comparison of internal anatomy, in particular the vital thoracic organs. One of the tools used to describe and study traumatic injuries in humans is the Abbreviated Injury Scale [3], but an equivalent system does not currently exist for canines Ideally this coding system would link back to human injury coding systems to allow for comparisons and injury assessments between handlers and working dogs. There are currently some veterinary injury coding schema available, such as the Animal Trauma Triage Scale (ATT) which assigns a severity score for trauma injuries and the modified Glasglow Coma Scale (mGSC) used just for neurologic injury, however these schemas use different injury binning techniques and offer no cross reference to human injury scoring schemas [4]. They also have no link to overall severities for comparisons between injuries. A new injury scoring system is needed for the establishment of a canine trauma registry to track and research traumatic injuries in working dogs [5].

The goal of this study is to investigate the thoracic anatomy and anthropometry between the human and canine to provide information about vital organ placement in relation to armour coverage areas and the potential for serious thoracic injury. This work will be used within a new project that aims to develop an injury coding schema and visualization tool for canine injury as well as body armour coverage analyses. This is an important tool for development to better understand traumatic injury to working dogs and their human counterparts.

## 2. METHODS

This study involved anlaysis of the canine anatomy and anthropometry using a representative computed tompography (CT) scan of a working dog. This scan of a 5 year-old, male Labrador Retriever was obtained from the U.S. Department of Defense Military Working Veterinary Hospital not for purposes of this study. The CT was acquired at 0.625 mm slice thickness using a 396 mm reconstruction diameter within 512 x 512 images, resulting in 0.773 mm in-slice resolution. The selection of the human CT scan used in this study was data-driven to identify an individual whose measurements are close to anthropometrics that represent the 50th percentile of a male U.S. Army soldier [6,7,8]. The CT was acquired at 1.25 mm slice thickness using a 500 mm reconstruction diameter within 512 x 512 images, resulting in 0.976 mm in-slice resolution. The U.S. Army representative male CT scan was acquired from U.S. Army Combat Capabilities Development Center Data & Analysis Center (CCDC DAC) via a collaborative research effort with Wake Forest University.

**Tabel 1.** Description of the measurements taken, the corresponding CT plane they were taken in and the human and canine nomenclature denoting anatomic orientation within that plane, along which the measurements were taken [7].

| Measurement | CT Plane | Anatomic View Within Plane | |
|---|---|---|---|
| | | Human | Canine |
| Depth | Sagittal | Anterior to Posterior | Dorsal to Ventral |
| Width | Axial | Left to Right | Left to Right |
| Length | Coronal | Superior to Inferior | Cranial to Caudal |

Both scans were acquired separately from this research, therefore the scans were constucted using slightly different protocols. Given the difference in the CT-scan orientation metadata, the scans were compared using anatomical planes. Table 1 details which human and canine anatomical plane corresponds to this study's measurement label. CT analysis was completed using Mimics software (Materialise, 20.0); each scan was analysed independently. This study initially focused on describing the heart, lungs, and span of the rib cage since these areas had been previously identified as important when considering ballistic plate design [9]. Three-dimensional (3D) geometry was created to represent the skin, skeleton, heart, and lungs of the male human and canine independently using segmentation


https://doi.org/10.52202/078352-0004

tools (thresholding, multi-slice edit, etc.). The measurement tool was used to take in-plane CT measurements. The objective was to investigate the location and relative size between the thoracic cavity and essential organs (heart and lungs). The plane with the largest area of the heart was used for the measurements to develop an estimate of coverage area for the vital organs. For each plane a linear measurement was taken of the heart, the lungs, the rib cage, and the chest (skin) at their widest points. The 3D geometry was a visual means of ensuring the measurements aligned with the most extreme points of each organ since those points did not always exist in the same plane. To quantify the space that the heart and lungs occupy in the human and canine, the depth, width, and length of the heart and lungs were measured, as they have the highest severity associated with organ injury within the thorax [3].

## 3. RESULTS

The canine chest is largest dorsal-ventral (Figure 1) whereas the human chest (Figure 2) is widest left-right. As shown in an axial view, the canine heart encompasses a large percent of the thoracic width behind the sternum and encompasses the full width of presented area of the chest, whereas the human heart is found within the center of the chest and is only a fraction of the anterior presented area of the chest.

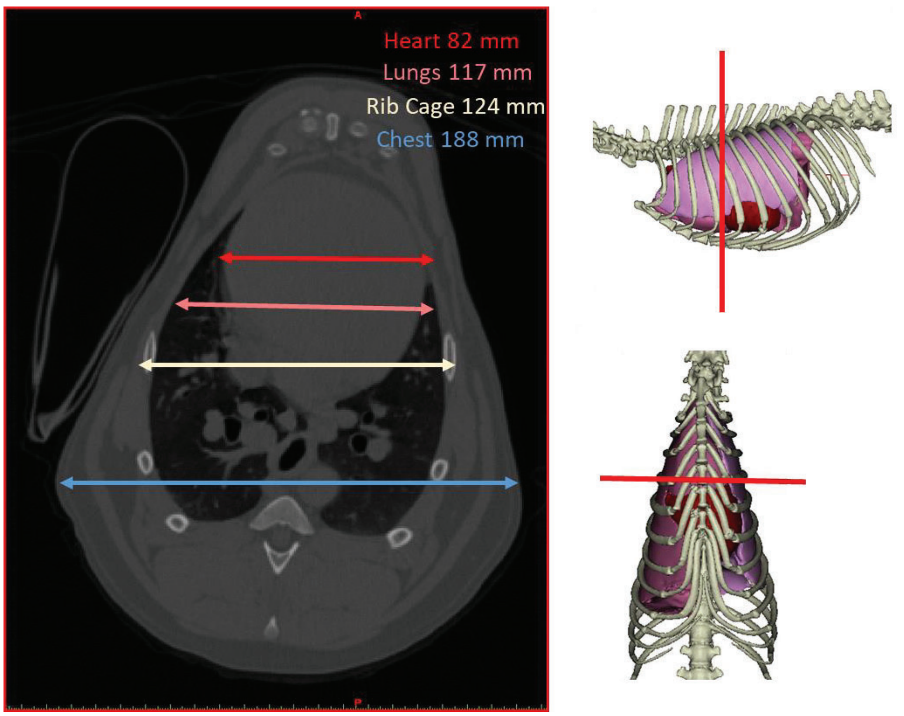


**Figure 1.** Axial cross section of the canine chest showing color coded lines where each tissue was measured within the slice. The arrows denote the width for each tissue: heart (red), lungs (pink), rib cage (pale yellow), and the chest (blue), measured at their widest point. Note that the canine in this view is oriented with the sternum at the top of the image, for comparison ease with the human CT shown in Figure 2.

 https://doi.org/10.52202/078352-0004

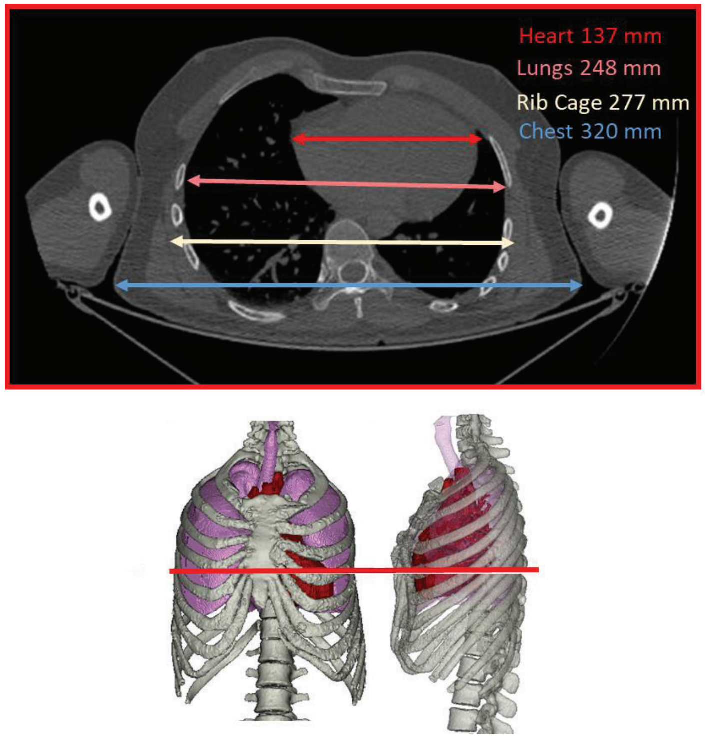


**Figure 2.** Axial cross section of the human chest showing color coded lines where each tissue was measured within the slice at each widest point. The arrows denote the width for each tissue: heart (red), lungs (pink), rib cage (pale yellow), and the chest (blue).

Figure 3 shows the thoracic anatomy and anthropometry from the ventral view (canine) and Figure 4 shows the anterior view of the human. The canine has 6 lung lobes – 4 on the right (cranial, middle, caudal, and accessory) and 2 on the left (caudal and cranial). In comparison, the human has 5 lung lobes – 3 on the right (superior, middle, inferior) and 2 on the left (superior and inferior).

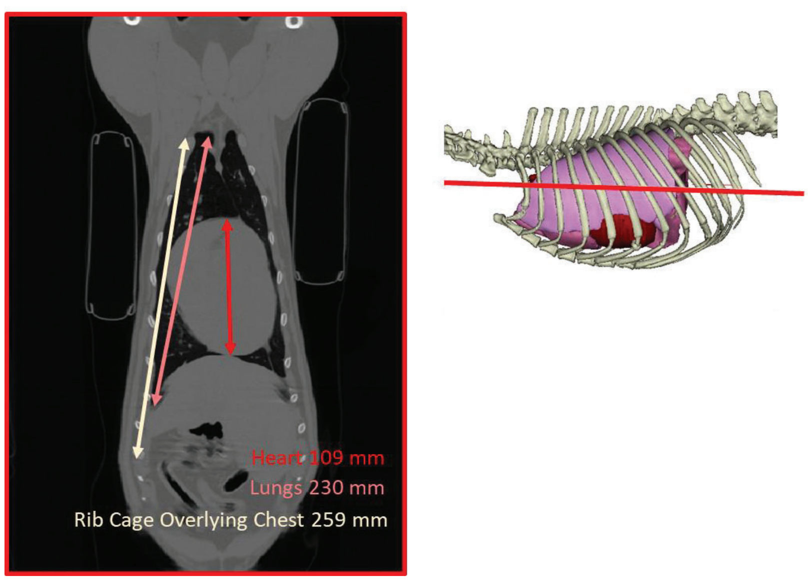


**Figure 3.** Coronal cross section of the canine showing color coded lines for where each tissue was measured within the slice. The arrows denote the length for each tissue: heart (red), lungs (pink), rib cage overlying the chest (pale yellow).


https://doi.org/10.52202/078352-0004

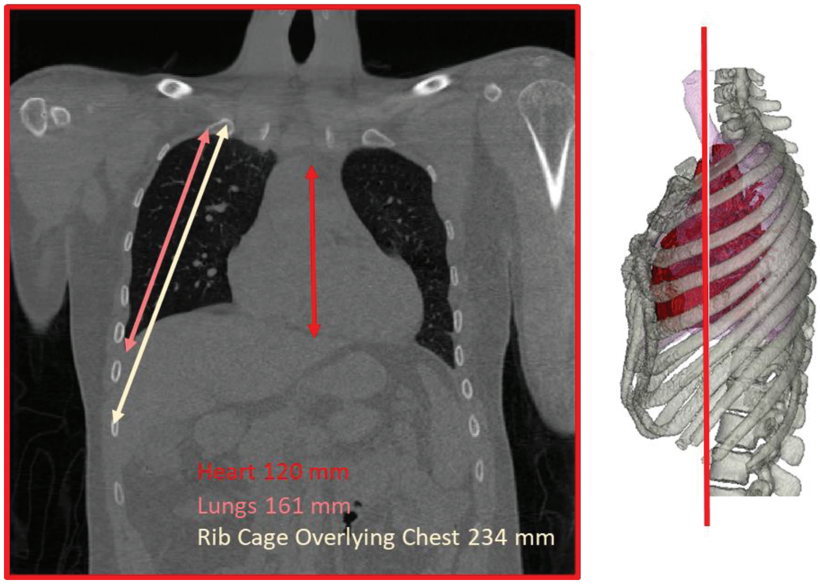


**Figure 4.** Coronal cross section of the human showing color coded lines for where each tissue was measured within the slice. The arrows denote the width for each tissue: heart (red), lungs (pink), and rib cage overlying chest (pale yellow)

Dorsal/posteriorly, the canine lungs encompass the areas underlying ribs 1-9, whereas in the human lungs encompass the areas underlying ribs 1-10. Ventral/anteriorly, this reduces to ribs 1-7 in the canine and ribs 1-6 in the human. This difference can be seen in Figure 5, where the rib cage, lungs, and heart are displayed for the canine and human.

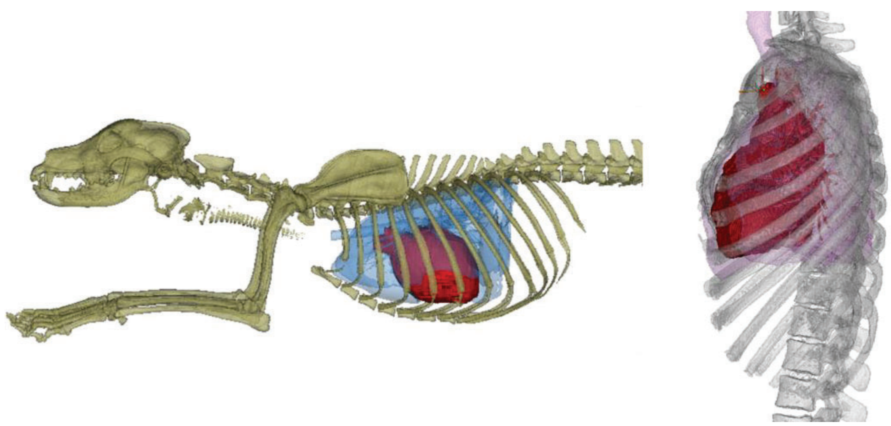

**Figure 5.** Anatomic view of heart, lungs, and skeleton of canine (left) and human (right) showing positioning of heart behind ribs, within chest cavity.

The apex of canine lungs is more narrow than that of the human, with the overall shape of the thorax in this view being more cone-shaped for the canine and more barrel-shaped for the human. Given this difference in shape, the canine heart is 70% of the width of the lungs, while in the human the heart is only 55% of the width of the lungs. The human heart is also more offset to the left compared to the canine. Table 2 details the final percentage of rib cage each organ encompassed for that measurement.


https://doi.org/10.52202/078352-0004

**Table 1.** Table of final measurements comparing percent coverage of the heart and lungs.

| | Percentage of Rib Cage Length/Width | |
|---|---|---|
| | **Human** | **Canine** |
| Heart Length | 51% | 42% |
| Lungs Length | 69% | 89% |
| Heart Width | 49% | 66% |
| Lungs Width | 90% | 94% |

## 4. DISCUSSION

With working dogs playing a significant role in our protection and safety alongside uniformed service members, it is important to understand their body armour requirements and the link between PPE and injury risk. Determining optimum coverage using anthropometrics and internal organ measurements can be difficult given the variablity within a species, let alone comparing anthropometrics across species. The last common classification in the phylogenic tree between humans and canines is the class Mammalia with humans then categorized as Primates and dogs as Carnivora. Both species' skeletal systems can be divided into axial and appendicular. Both axial skeletons have a rib cage to protect thoracic organs but with the human commonly having 12 ribs on each side and the canine having 13. Since both the human and canine have similar skeletal structures, the rib cage was used as a skeletal feature to compare organ location and anthropometry [7,10]. Furthermore, past studies have supported a higher correlation of skeletal landmarks to internal anatomy placement, as opposed to external soft-tissue landmarks (e.g., nipples and umbilica) [6,11].

After reviewing the anatomy and anthropometry between the male canine and human, the canine thoracic stature in a standing position more closely reflects the human in the prone position. When prone, the human head is presented first, with the neck and top of the chest the most vulnerable area of the thorax. For canines, both sides are exposed as well as the front of the chest, leading with their heads. For canines, body armour designs to fully protect against small arms and fragmenting threats will need side coverage as well as frontal coverage – potentially requiring 3 panels of protection versus the 2 that are currently offered with human body armour. This is especially true for situations that involve the canine advancing towards a threat, where their chest is the largest presented area and the majority of that surface area overlies the heart. As shown by the CT scan in Figure 1, the entire presented area of the chest for the canine is encompassed by their heart – leaving a vital area susceptable to lethal injury. While this initial study is developed from the CT scans of one male canine and one male human, they are representative of the standard population size that is relevant for the US male soldier and working dog. Future work would benefit from the inclusion of additional CT scans from representative subjects. Additionally, for the canine, this work is specific to dogs of a similar body size and shape to that of a working dog. There are many shapes and sizes of dogs where this data would not be relevant, such as brachycephalic dogs or much smaller/larger breeds.

There is not currently a standard test and body armour rating system that is specific to canines. Given the differences in anatomy and anthropometry, it is important to consider whether human test standards are appropriate for the canine, especially when investigating coverage areas with injury severity. Most canine body armours found for sale stated they were tested to the same NIJ standards as human body armour, but there is currently not a transfer function between canine and human thoracic injury [12]. To aid in this transition and comparison of injuries, it is necessary to apply a traumatic coding system to canine injury in the same way that AIS is used for humans. This task is currently underway and will result in a traumatic injury scoring system for the canine that is analagous to human AIS codes. There are important orientation and anatomical differences between the canine and human thoraces that need to be taken into account when developing a parallel injury coding schema. The lungs in the canine are structured with 4 on the right and 2 on the left, so that an injury to one or two lobes may not be as catatrosphic compared to human lung injury. Galer noted that pneumothorax in a canine can be treated with a chest tube very similarly to that of a human and canines have a fenestrated mediastinum so that a chest tube on one side may help with a pneumothorax on the other [13]. When analyzing shotlines and body armour coverage areas, the sides for the canine are a large presented area that leave the heart and lungs vulnernable to injury. While side impacts to the human are similarly damaging shotlines


https://doi.org/10.52202/078352-0004

encompassing both lungs and the heart, the coverage area for the side on a human is much smaller than that of the dog.

This work is contributing to the development of a canine injury coding system that will be used to standardise injury research and body armour protection for working dogs. This coding system is being developed from the human Abbreviated Injury Scale [3]. In human AIS codes, there are 191 codes for the chest. This includes the ribs, heart, lungs, bronchus, major arteries and veins, and trachea. Codes and descriptions must be altered for the canine. For example, the human AIS chest injury description of “breast avulsion” is not applicable to the canine. Once complete, it will be possible to compare canine injury and human injury from the same events in both the law enforcement and military scenarios. This is important for learning about emerging threats, body armour development, and injury comparisons to laboratory test data. Standard police and military working dogs stand at about knee-high for the human, making their injuries important for forming comparisons to human leg and foot injuries in blasts. The long-term goal of this effort is to develop a comprehensive canine traumatic injury scoring system for recording injuries and developing protective measures, increasing survivability for the working dog as well as the uniformed service members.

## 5. CONCLUSION

By investigating the comparative anatomy and anthropometry between the working canine and human, it is possible to develop better protection for our working dogs, making them more effective partners for their human counterparts. While much research has gone into human body armour protection areas, injury risk, and lighter-weight armour, the same is greatly lacking for the working canine. This research showed that the chest of the canine should be covered with body armour to best protect the dog when facing a threat, especially since the heart spans the entire width of the chest. Additionally, there is a need to develop a traumatic injury scoring system for the canine that is analagous to the system used in human injury research so that comparisons and crosswalks between injuries can be completed. Working dogs work alongside their human counterparts and the protection of the canine is vital for the team to function as a whole.

**Acknowledgements**

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https://doi.org/10.52202/078352-0004