Working Like Dogs: A systematic evaluation of spinal pathologies as indicators of dog transport in the archaeological record

by

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Abstract

The use of dogs for pulling or carrying loads is well documented in the recent and historic past in many parts of the world. While the use of dogs for similar activities in prehistory seems likely, there is little artifactual evidence in the archaeological record to support such speculation. Some archaeologists have suggested that pulling or carrying loads may leave unique signatures of stress on the skeletons of dogs used for these activities and that such skeletal indicators may be used to identify the utilization of dogs for transport in archaeological assemblages.

The utilization of skeletal indicators for identifying archaeological dogs used for pulling or carrying loads is largely based on observations of prehistoric dog remains and archaeologists' interpretations of veterinary literature on dogs and other draft animals, including a famous study of the mid-20th century British Antarctic Survey sled dogs. Several pathologies, including the spinal pathologies spondylosis deformans, and the occurrence of bent, fractured or otherwise deformed spinous processes, all have been suggested as potential skeletal indicators for these types of dog transport.

Though the use of skeletal indicators is appealing, there have been no large scale studies evaluating the occurrence of such lesions among both wild canids and dogs never used for pulling or carrying loads. In the absence of such data it is unclear if it is appropriate to attribute these skeletal abnormalities to specific occupational etiologies. Many of the indicated pathologies are also positively correlated with the aging process and are commonly found in older dogs. Spondylosis deformans occurs in many animals and has been shown to have possible sex and genetic components and to be more common in certain breeds and types of dogs. It thus seems possible that the indicators thought to be correlated with the use of dogs for transport may

in fact actually reflect genetic and aging processes rather than their habitual activities. This possibility is especially hard to eliminate when dealing with archaeological dog specimens, which are often fragmented and their age, sex, and life history unknown.

This study systematically analyzed the occurrence of spondylosis deformans and spinous process deformities in 155 modern dogs never used in transport activities, 19 sled dogs, and 241 wild wolves to evaluate the reliability of these pathologies as indicators of dog transport in archaeological assemblages. Results of this analysis suggest that spondylosis deformans is not a reliable skeletal indicator of dog transport because both dogs and wolves are affected by the disease at high rates that cannot be distinguished from other etiologies.

Due to methodological challenges, analysis of spinous process deformities was inconclusive and the reliability of such deformities as skeletal indicators of transport remains uncertain. However, comparison between the results of this study and previous archaeological studies suggests that patterns of spinous process deformities in archaeological populations are different from those seen in modern dogs and wolves and are worthy of further investigation. Ultimately, this study highlights the need for better understanding of the causes of bent spinous processes, and the natural range of spinous process deformities in canids, as well as a standardized methodology for measuring and describing these deformations in archaeological specimens.

I was told several times by the Reindeer people, “The Russians unjustly wonder why we keep so many dogs. The dog is the guardian of man, a strong help in every misfortune, a true friend, keeping off the Evil One.” In travelling, a dog as a companion frightens the evil spirit away, while a reindeer has no such power.

~ Waldemar Bogoras, *The Chukchee* (1909)

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Chapter 1 : Introduction

The relationship between humans and domestic dogs is of great antiquity and complexity. Dogs began living with humans by at least 15,000 years ago (Larson et al. 2012; Savolainen 2007; Thalman et al. 2013; Wayne and von Holdt 2012). As a large carnivore and direct descendant of Eurasian wolves (Frantz et al. 2016; Vila et al. 1997; Wayne and Vila 2001), the dog seems a conspicuous choice of companion for prehistoric humans, yet was the first animal to be domesticated. While questions regarding how and when this relationship began have yet to be answered it is clear that, as man's oldest and 'best friend', dogs have accompanied humans to all reaches of the globe and in some places, even to the afterlife (Larson et al. 2012; Losey et al. 2011). The consistent physical and ritual inclusion of dogs within the social interaction sphere of humans in the past suggests that dogs were of great importance for many of the peoples who kept them.

Despite the prevalence of dogs throughout the ancient world, there is little evidence for how humans interacted with or utilized their canine companions prior to the advent of written records. Historically, dogs were commonly bred to create individuals particularly suited for specific types of jobs such as herding, scenting, guarding, and retrieving. In the modern era and the recent past dogs have fulfilled a variety of roles in aid of their human companions including as a means of transport, food, hunting partners, and for companionship.

While it seems reasonable to infer that dogs may have filled similar roles in prehistory, it is difficult to substantiate such speculation. Significant evidence suggests dogs were consumed by some groups in the past (Morey 2010; Olsen 1985; Snyder 1995), but little other archaeological evidence remains to inform us of other past uses for dogs. Based on the extensive historic use of dogs to pull or carry loads, or what will generally be referred to as dog transport henceforth, it seems likely that humans also utilized dogs for this purpose in the distant past. Unfortunately, the types of materials and hardware described in historic documentation of dog transport were commonly made of perishable materials which were often recycled and would not be expected to survive archaeologically in most environments (Bleed 2006; Morey and Aaris-Sorensen 2002).

Understanding the history of the use of dogs for transport is of particular archaeological significance in areas such as the Arctic or the Great Plains of North America where these activities were common in the early contact period (Allen 1920; Bogoras 1909; Damas 1984; Lowie 1954; Morey and Aaris-Sorensen 2002; Morey 2010; Wilson 1924). We can reasonably suspect that such practices also substantially impacted the mobility and lifeways of peoples in these regions in the past. In the absence of significant artifactual evidence, it has been difficult to understand when these peoples began utilizing dogs for transport activities or how human mobility was influenced by such practices once they appeared.

One solution to this problem has been to look for other ways of identifying dog transport using the skeletal remains of dogs found in archaeological assemblages. Multiple authors have suggested that the use of dogs for such tasks might leave a signature on their skeletons (Arnold 1979; Millar 1978; Morey and Aaris-Sorensen 2002; Snyder 1995; Warren 2004). If that signature is unique to dogs used for transport activities, then it might be possible to infer that dog transport was being used at a particular site based on skeletal remains alone.

Specific skeletal indicators of such behaviors have been proposed based upon observations of archaeological dog remains and archaeologists' interpretations of veterinary literature on dogs and other draft animals, including a famous study of the mid-20th century British Antarctic Survey sled dogs. This source reported that a group of dogs used for pulling sleds suffered from high rates of osteoarthritis affecting the shoulder and hip sockets and the limbs, as well as spinal pathologies which include degenerative disc disease (spondylosis deformans) and in some cases flattened or bent spinous processes (Bellars and Godsal 1969; Bellars 1969). The patterns observed in this study have since been used to suggest that these osteoarthritic processes and spinal pathologies might be used as indicators of dog transport when found in archaeological dogs (Snyder 1995; Warren 2004).

While the studies of the British Antarctic Survey and subsequent archaeological studies are intriguing, it is unclear if it is appropriate to attribute such skeletal abnormalities to specific occupational etiologies. Many of the indicated pathologies are also positively correlated with the aging process and are commonly found in older dogs. Further, spondylosis deformans has been shown to have possible sex and genetic components and to be more common in certain breeds and types of dogs. This spinal pathology also has been found to occur among canids such as foxes and wild wolves (Harris 1977; Räikkönen et al. 2009, 2006). It thus seems possible that the indicators suggested to be correlated with the use of dogs for transport may in fact actually reflect genetic and aging processes rather than their habitual activities. This possibility is especially hard to eliminate when dealing with archaeological dog specimens which are often fragmented and whose age, sex, and life history are unknown.

However, the primary reason the pathological lesions reported archaeologically and in the British Antarctic Survey's sledge dogs are difficult to use as clear indicators of burden pulling or hauling is that there have been no large scale studies evaluating the occurrence of such lesions among both wild canids and dogs never used for carrying or hauling burdens. Without such data, we lack a clear understanding of the normal pattern of variation typical of dogs and other canids.

In other words, it is difficult to argue that these types of lesions can be used as skeletal indicators because there is no way to demonstrate that such lesions are unique to dogs utilized for transport.

This thesis evaluates the occurrence of spondylosis deformans and bent spinous processes in a sample of modern dogs and wild wolves never used for transport activities, and in a small sample of sled dogs. If these spinal pathologies are useful indicators of load pulling or carrying, then we should expect them to occur at comparatively high rates among sled dogs when compared to canids not used for these purposes.

To evaluate the usefulness of these pathologies as indicators of transport activities in archaeological dogs, this study will ask the following questions: What are the occurrence rates and forms of such lesions in the canid populations examined? Is spondylosis deformans common in wolves and pet dogs despite the fact that they never pulled or carried heavy loads? What is the range of variation in spinous process shape in canids? Is some degree of deformation (not perfectly vertical) common in such animals? Are the rates and locations of such lesions and deformations significantly different in dogs and wolves, and how do these compare to archaeological dog populations where burden hauling or carrying is suspected?

The following chapters will explore dog transport and the use of skeletal indicators for identifying this activity in archaeological assemblages. Chapter 2 provides an overview of the history of dog domestication and utilization in the recent and historic past, and in the prehistoric archaeological record. Chapter 3 discusses the basis for and use of skeletal indicators of dog transportation by archaeologists and poses research questions for testing and evaluating spondylosis deformans and spinous process deformations as such indicators. Chapter 4 explains the materials and methods used in this thesis. In Chapter 5 a comprehensive summary of the results of this research is provided followed by a discussion of these results in Chapter 6. Final conclusions and implications for future research are posed in Chapter 7.

Chapter 2 : A History of Dogs

The domestic dog is a direct descendant of Old World gray wolves (Clutton-Brock 1995; Lindblad-Toh 2005; Vilà et al. 1999, 1997; Wayne and Vilà 2001) and appeared in Eurasia sometime between 15,000-45,000 years ago (Larson 2012; Savolainen 2007; Savolainen et al. 2002; Thalman et al. 2013; Wayne and von Holdt 2012). For the past two decades there has been considerable debate among archaeologists and geneticists about the origins and initial domestication of the dog. At the heart of this debate have been questions regarding whether the first dogs appeared as a result of a single event (Crapon de Caprona 2013; Ding et al. 2011; Pang et al. 2009; Savolainen 2007; Savolainen et al. 2002; Wang et al. 2013) or multiple independent domestication events (Verginelli et al. 2005; Vilà et al. 1999, 1997; vonHoldt et al. 2010; Wayne and Ostrander 2007; Wayne and vonHoldt 2012) and when and where these events occurred. European (Verginelli et al. 2005; vonHoldt et al. 2010; Wayne and vonHoldt 2012), Middle Eastern (vonHoldt et al. 2010) and East Asian (Crapon de Caprona 2013; Ding et al. 2011; Leonard et al. 2002; Olsen 1985; Pang et al. 2009; Savolainen 2007; Savolainen et al. 2002; Wang et al. 2016; Wang et al. 2013) domestication centers have all been suggested. The most recent genetic research suggests that independent domestication events occurred in both Europe and Eastern Asia, but at some point between 6,400 and 14,000 years ago dogs of East Asian descent largely replaced early European forms (Frantz et al. 2016).

If this interpretation is correct it may help to explain what many have viewed as a discrepancy between the archaeological record of dogs and their genetic record. Despite genetic evidence for dogs of East Asian ancestry, the oldest archaeological dog remains have been recovered from European and Western Siberian sites (Morey 2010; Larsen et al. 2012; Savolainen et al. 2002). The interpretation of Frantz et al. (2016) may also shed light on a group of ~30,000-year-old specimens which some have argued represent early domesticated canids (Druzhkova et al. 2013; Germonpré et al. 2015; Germonpré et al. 2012; Germonpré et al. 2009; Ovodov et al. 2011). One of these specimens, a putative dog from the Altai Mountains of Siberia dated to 33,000-33,500 cal B.P, has been identified as a domestic dog based on DNA analysis (Druzhkova et al. 2013). Another specimen, a canid skull from Belgium dated to 31,700 BP, has also been put forward as an early dog. The specimen appears morphologically similar to dogs but DNA analysis shows that it is not directly related to modern wolves or dogs and "may represent aborted domestication episodes" (Germonpré et al. 2009; Thalman et al. 2013:874). As of now, the status of these canids as early domesticates remains disputed (Crockford and Kuzmin 2012; Drake et al. 2015; Morey 2014; Morey and Jeger 2015).

Currently the oldest widely accepted evidence for domestic dogs comes from the Bonn-Oberkassel site in Germany where a 15,000-year-old dog was discovered in the context of a human burial (Benecke 1987; Morey 2010). Dogs of similar age have also been reported from sites in Switzerland (Napierala and Uerpmann 2012), Ukraine (Germonpré 2009; Morey 2010), and the Central Russian Plain (Sablin and Khlopachev 2002) but skeletal remains of dogs do not appear in the East Asian record until the early Holocene (Matsui 2008:148; Savolainen et al. 2002:1613).

Regardless of when and where domesticated dogs first appeared, it is clear that they were the first domesticated animal and that they began living among humans several thousand years before the domestication of plants and other animals (Clutton-Brock 1995; Larson et al. 2012: 8878; Morey 2010; Zeder 2012). It is also clear that shortly after dogs begin to appear in the archeological record, they began to rapidly spread throughout the world, almost certainly alongside of their human companions (Larson et al. 2012; Leonard et al. 2002; Morey 2010;

Olsen 1985). By the Middle Holocene dogs are found on every continent occupied by humans (Larson et al. 2012; Morey 2010; Olsen 1985; Tito et al. 2011).

The appearance of domestic dogs marks a major technological and cultural shift that ultimately expanded human capabilities and changed the way humans thought about and used animals. This shift is most apparent in the sudden appearance and proliferation of dog burials some 14,000 years ago (Morey 2010, 2000; Losey et al. 2011; Shipman 2011). Throughout much of the prehistoric world dogs are found as inclusions in human burials or afforded individual burials in which their remains are given the same mortuary treatment as that given to humans (Losey et al. 2011; Mannermaa et al. 2014:28; Morey 2010). This sort of ritualized treatment of dogs alludes to a unique and complex social relationship between humans and their canine companions which seems to have been established early on.

Dogs from the prehistoric era are most commonly found in the context of burials (Benecke 1987; Davis and Valla 1978; Losey et al. 2011, 2013; Mannermaa et al. 2014:28; Matsui 2008; Millar 1978; Morey 2006, 2010; Olsen 1985; Wayne and vonHoldt 2010), middens (Matsui 2008; Morey 2006, 2010; Olsen 1985), living spaces (Benecke 1987; Morey 2006, 2010; Olsen 1985; Sablin and Khlopachev 2002), kill sites and processing sites (Davis and Stallcop 1965; Dyck 1977; Germonpre et al. 2009; Gregg 1987; Morey 2010; Unruh 2008; Walker 1982; Walker and Frison 1982; Widga 2006). Due to the morphological similarities between wolves (*Canis lupus*) and domestic dogs (*Canis familiaris*), distinguishing between the two species in an archaeological context can be extremely difficult for even the most skilled osteologist (Morey 2010). While this fact has complicated the identification of very early examples of domestic dogs in the archaeological record, the phenotypic similarity between these two species can be useful when assessing the physical impacts of domestic environments upon the skeletons of dogs, including their working relationships with humans. In other words, wild wolves can be used as a control with which to compare dogs.

Historic Utilization of Dogs

Throughout the historic period dogs have been utilized to perform a number of specific jobs for humans. Most of us are familiar with the use of dogs for herding, protection of property or individuals, hunting, and as guides for the blind or handicapped. In addition to these well-known uses, dogs have also been utilized by humans as a source of wool for blankets (Schulting 1994), as food (Bozell 1988; Morey 2010; Olsen 1985; Snyder 1991), and for transport (Allen 1920; Bogoras 1909; Damas 1984; de Lavigne 2014; Lowie 1954; Mannermaa et al. 2014; Morey and Aaris-Sorensen 2002; Morey 2010; Wilson 1924).

The use of dogs for pulling or carrying loads is well documented in the ethnohistoric and ethnographic literature from many parts of the world. In the recent and historic past dogs were used in the Arctic and Sub-Arctic regions to pulls sledges and carry packs (Arnold 1979:263; Damas 1984; Mannermaa et al. 2014; Morey and Aaris-Sorensen 2002:44), on the Great Plains of North America to pull travois and carry packs (Allen 1920:449-455; Bozell 1988:97; Grinnell 1966:63; Lowie 1954:40; Wilson 1924), and in Western Europe to pull carts (de Lavigne 2014).

Dog-sledges were used by peoples of the Eurasian and North American arctic regions in the historic past, and are still used by some groups for both sport and transport today (Bogoras 1909; Damas 1984; Morey 2010; Morey and Aaris-Sorensen 2002:44-45). Early explorers of the Siberian Arctic reported the use of dog-sledges in the late 19th century (Bogoras 1909:58; Samar 2010). For example, in 1909 Waldemar Bogoras reported that three groups were known to utilize dogs for this purpose in Asia. These groups used harnesses and traces to attach teams of dogs to various sled types, and teams typically consisted of 6-14 dogs arranged in pairs (Bogoras 1909:98-100). The use of sled-dogs has also been documented in northwestern Russia in the Karelia (Mannermaa et al. 2014:27).

Similarly, the use of dog-sleds is described throughout the North American Arctic during the historic era. Early accounts of the use of sled dog teams in the region were reported by missionaries during the first part of the 18th century (Brown et al. 2013:1280). Sleds were commonly used for long distance travel and transportation to hunting and fishing sites (Damas 1984). Sled and dog-team sizes and configurations varied greatly between regions, cultural groups, and through time (Loovers 2015). For instance, among the Nunivak Eskimo, small sleds were pulled by a combination of dogs and humans tied to the sides of the sled (Lantis 1984:215). On Baffin Island teams of 2-6 dogs were used in the Hudson Strait and Cumberland Sound regions and teams of 6-12 along Davis Strait (Kemp 1984:469). In Western Greenland teams were comprised of approximately seven dogs per sled (Kleivan 1984:602).

In the North American Arctic dogs were also used by several groups to carry packs, often in the summer months when sleds could not be used (Damas 1984). Among the Inuit of Quebec, "the dogs carried bags of provisions and utensils, and even sometimes an infant, and dragged the tent poles" (D'Anglure 1984:485). These types of loads were also typical of other groups utilizing dog packs (Damas 1984). When the snowmobile was introduced in the 1960's and 1970's it increasingly replaced the use of dog transport throughout the North American Arctic (Hughes 1984:271; Vallee et al. 1984:664-665).

On the Great Plains the domestic dog was of vital importance, serving as the only means of transport prior to the introduction of the horse in the early 18th century (Bozell 1988:97; Lowie 1954:39-40; Snyder 1995:2; Wilson 1924:141) as well as an occasional source of food

(Lowie 1954:34-40; Snyder 1991, 1995; Wilson 1924:30). The demand for large strong dogs to accommodate these needs was facilitated by large population sizes and directed breeding programs (Bozell 1988; Wilson 1924:199-200).

Numerous ethnographic and ethnohistoric accounts document the use of dogs for transport throughout the Great Plains during the historic era. The earliest mention of the use of dogs for transport in the region was made around A.D. 1540 by the conquistador Francisco Coronado on his journey from the City of Mexico to the Texas Plains (Allen 1920:454). Later explorers including Lewis and Clark (Allen 1920:455; Snyder 1991: 363), Stephen Long (Snyder 1991:363), John T. Irving, Charles A. Murray, John Dunbar, Samuel Allis (Bozell 1988:95-97) and others (Snyder 1991:360-363) also reported the use of dogs for transport as well as food in their historic accounts of the Great Plains. Ethnographic accounts of dog usage are also provided, including those by Gene Weltfish (Bozell 1988:97) and more famously, Gilbert Wilson, who reported extensively on the use of dogs for transport among the Hidatsa as told to him by Buffalo-Bird-Woman (Wilson 1924).

The travois was the most common form of transport on the Great Plains. It consisted of two poles approximately eight feet in length (Wilson 1924:220) that were bound together at one end to form an “A” frame. The narrow, bound end of this frame was attached to an individual dog by a harness with the long, open ends dragging on the ground behind the animal. Mid-way between the closed and open ends was a cross beam or basket to which a load could be secured (Allen 1920:453-454; Lowie 1954:40; Wilson 1924:217-220). A bison fur saddle sat between the travois poles and the dog’s neck and shoulders in order to relieve some of the weight of the load (Wilson 1924:219-220).

According to Lowie (1954:40) the travois was most prevalent north of the Platte River, though Allen (1920:453) suggests variations were present from the Mexican boundary of the Plains to Saskatchewan. As many as 37 tribes were reported to have used the travois on the Northern and Central Plains. Twenty-one of these tribes, including the Teton, Hidatsa, Mandan, Arikara, Pawnee, Santee, Iowa, Kansa, and Arapaho were said to have used only travois. Ten tribes including the Blackfoot, Gros Ventre, Crow, Cheyenne, Wind River and Comanche tribes were have said to use both travois and packs, while six groups used either travois or packs. When Coronado and his men encountered the Teyas and the Querechos it was noted that their dogs were equipped with a system which combined both pack and travois (Lowie 1954:42).

Various sources estimate that a dog using a travois could carry 60-100 pounds (~23-45 kg), depending upon the size of the dog (Henderson 1994:157; Wilson 1924:208). Travois dogs were utilized for a variety of purposes including moving tipi poles and other supplies during residential moves, and carrying supplies for hunting parties. The nature of their usage changed following the introduction of the horse and the subsequent adaptation of travois to fit this larger, stronger animal (Bozell 1988). According to Buffalo-Bird-Woman, after acquiring horses the Hidatsa used travois dogs primarily for gathering firewood, relying on them "nearly daily" for this activity (Wilson 1924:219).

Packs, which were placed directly on a dog's back to carry loads, have also been described on the Great Plains although considerably less is known of their usage when compared to the travois. The Assiniboine were known to use dog packs that were "made up of two skin pouches cinched around the middle" (Morey 2010:92). Bozell (1988:97), citing Weltfish (1965:160-161) stated that the Pawnee used a "dog sack" which looked similar to saddle bags. It has been noted that some tribes used dog packs for carrying extra moccasins when travelling long distances or setting out for a raid (Grinnell 1966:63; Lowie 1954:40), but little else is known about how dog packs were used.

In Europe, dogs were used to pull both carts and carriages since the Roman period. In a third century text the early historian Lampridius stated that the Emperor Heliogabalus used dogs to pull carriages (de Lavigne 2014:14). The use of dogs to pull carts and carriages is more thoroughly documented by the 16th century, when such practices became a common and comparatively inexpensive alternative to the use of horses. In Belgium, Holland, and France dog carts were used to carry goods and people to and from markets. In Bavaria, dog-carriages were a sign of wealth and used by elites for transport and racing (de Lavigne 2014:14-15).

In Switzerland the Sennenhunde, or Greater Swiss Mountain Dogs, are a symbol of the dairy industry. When Swiss dairies moved their operations out of the mountains and into the valleys in the mid-19th century the dairies began using dog-drawn carts, often pulled by Sennenhundes, to move milk cans from the pastures to the valley. Dog-carts were also used to transport cheese from village to village for sale (de Lavigne 2014:17-18).

By the end of the 19th and into the early 20th century dog carts were used all over Europe to move people and goods. Large strong dogs were used to pull a variety of cart and carriage types, both individually and in teams. The rise of cities during this period combined with a shortage of horses promoted this increase, as dogs were more affordable for peasants and could maneuver city streets better than horses. By 1900, 150,000 draft dogs were registered in Belgium alone (de Lavigne 2014:18-19).

Prehistoric Utilization of Dogs

Though dog remains are very common at prehistoric archaeological sites throughout the world (Morey 2010; Olsen 1985), very little is known about how humans utilized their canine companions. The only clear use of dogs during the prehistoric period was as food. Evidence of processing dogs in the form of burned bones and cut-marks indicative of butchering are found at a number of archaeological sites worldwide and the practice is well documented in the ethnographic and ethnohistoric record (Mannermaa et al. 2014:35; Morey 2010; Olsen 1985; Snyder 1991).

The earliest possible evidence for the use of dogs in transport activities is found in the Arctic. Dogs likely first appeared in the Western Arctic region and later spread into North America and the easternmost regions (Brown et al. 2015, 2013; Damas 1984; Leonard et al. 2002). When and where they first appeared in the Western Arctic is less clear. Some have reported that dogs were present in Kamchatka between 10,360 BP to 10,760BP though the dates for these specimens, as well as their identification as dog remains, have been questioned (Lee et al. 2015:2; Olsen 1985:66). A recent study of prehistoric canid genetics has suggested that domestic dogs were present in Arctic Siberia by at least 8000 14C YBP on Zhokhov Island (Lee et al. 2015:7). These dates seem more reasonable as similar early evidence for dogs comes from the nearby sub-arctic Lake Baikal region at the Ust'-Khaita site where Losey et al. (2013) have suggested dogs may have been present as early as 12,380 to 12,135 calBP, and are well-evidenced by 7000 years ago. Dogs have also been identified in archaeological sites in Northern Europe and the Baltic region. Dogs appear to have been present at Pulli (~11,000-10,000 calBP) and Lammasmägi (c 10,000–9000 calBP) in Estonia, and at the Nissbacka site in Southern Finland dated to c 9257–9021 calBP (8180±90 BP) (Mannermaa et al. 2014:25-26).

In Arctic Siberia, sled runners and possible harness parts dating to approximately 8000 BP suggest that sled technology was present in the region by the Mesolithic (Pitulko and Kasparov 2016). Harness parts found at the Ust'-Polui site in Western Russia from around 2000 years ago provide the earliest evidence that humans in the region were utilizing animals in transport activities, though it is not clear which animals (dogs or reindeer) were being used at that time (Fedorova 2000; Gusev 2014). At this same site, a small knife handle was found that appears to be carved in the shape of a dog wearing a harness. It also dates to about 2000 years before present and is thought by some to be the earliest evidence for dog sledding in the Arctic (Chernetsov and Moszynska 1974). There is, however, no direct evidence for the use of dogs for pulling sleds prior to the modern era.

Though dogs have been reported from Paleoeskimo contexts (ca. 4000 BP) in the Eastern Arctic they are rare during this period and do not become common in Eastern Arctic assemblages until about 1000 years ago during the Thule phase (Morey and Aaris-Sorensen 2002:45-47). The earliest evidence for the use of dog sleds in the Eastern Arctic is also associated with the Thule culture. According to Morey and Aaris-Sorensen (2002:45), "Thule sites, at least in all but the southernmost reaches, routinely yield not only numerous bones of dogs, but also sled parts and other associated material remains, including trace buckles and whip shanks." Dog sled technology in the Eastern Arctic seems to have appeared on the Northwest coast and spread westward across North America with the Thule diaspora (Morey and Aaris-Sorensen 2002:45).

On the Great Plains of North America dogs were present as early as 9000 years ago (Tito et al. 2011) and are quite common in archaeological assemblages by about 6000 years ago (Widga 2006). Despite their long history in the region there is no artifactual evidence of dog transport on the Plains prior to the historic period. This is not surprising given that the wooden and fibrous materials used to construct a travois (Wilson 1924:217-218) are not conducive to preservation in most archaeological settings.

Chapter 3 : Skeletal Indicators of Transport in Dogs

As the internal framework of the body, the skeleton plays a central role in locomotion and activity. The bones that make up the skeleton are organs that actively maintain and remodel themselves throughout life. Bone responds to stress and damage by growing new bone to repair damage or compensate for stress in a strained area. These processes often leave various unique signatures on the surfaces of bones. In archaeological remains, such skeletal signatures can provide information on the life history of an individual, offering some insight into their habitual physical activities (Kennedy 1989:134).

In lieu of hardware or other artifactual evidence for the use of dogs in transport, some authors have attempted to identify indicators of such activities in archaeological dog remains (Arnold 1979; Millar 1978; Snyder 1995; Warren 2004). These indicators are mainly pathological lesions associated with trauma or mechanical and physical stress that have generally been observed in archaeological dogs from regions where dog transport is well documented in the historic era.

Aside from archaeological observations, the identification of specific pathologies as indicators of load bearing is based largely upon a mid-20th century study of the British Antarctic Survey's sledge dogs which argued that pulling heavy loads has a marked effect on the skeletons of such dogs (Bellars 1969; Bellars and Godsal 1969:15). Specifically, the British Antarctic Survey found unusually high rates of osteoarthritis in the shoulder and hip joints of their sledge dogs (Bellars and Godsal 1969:15). Osteoarthritis is characterized by "deterioration of the bone and cartilage of one or more joints" (Burt et al. 2013:4). Over time this deterioration can cause the bones of the joint to rub against one another resulting in "distortion of joint position… pains, swelling, and stiffness in the living individual" (Burt et al. 2013:4). Among the Antarctic

Survey's sledge dogs, the progression of osteoarthritis made it impossible for severely affected dogs to work and was the primary reason dogs had to be put down (Bellars 1969:17).

Bellars and Godsal (1969:34) also observed the occurrence of spondylosis deformans in the spines of 9 out of 11 of the British Antarctic Survey dogs between the ages of five and ten years old. Spondylosis deformans is a condition in which small spurs of bone, or osteophytes, grow on the surfaces of vertebral bodies near the intervertebral discs that prevent bone to bone contact between vertebrae. In severe cases the growth of osteophytes can deform or even fuse adjacent vertebrae. Spondylosis deformans is related to degeneration of the intervertebral discs and is typical of the aging process, but also can be caused by mechanical stress (Burt et al. 2013; Morgan 1967:8).

Though Bellars and Godsal (1969:34) noted that the pattern of spondylosis deformans observed was not unusual for dogs of advanced age, several authors have continued to suggest a link between the presence of this disease in archaeological dog remains and the use of those dogs in transport activities (Arnold 1979; Millar 1978; Snyder 1995; Warren 2004, 2000).

For example, Arnold (1979:264) noted the occurrence of spondylosis deformans in a Paleoeskimo period dog from Banks Island in the Northwest Territories. In this dog three articulating vertebrae (T12-L1) were affected with osteophytes as well as flattening and lipping of the spinous processes of these vertebrae. The author speculated that these pathologies might indicate "the use of a pack or harness" and that "In this respect, the osteophytoses could be bone responses aimed at strengthening the flexible vertebral column of a pack animal."

Similarly, on the Great Plains, Millar (1978) observed the occurrence of osteophytes on three lumbar vertebrae as well as broadening and flattening of the spinous processes in the last two thoracic and “four lumbar vertebrae” in a dog burial at the Oxbow period Gray site in Saskatchewan. Pathologies of the pelvis and femora were also observed. Millar speculated that “The combined pathological changes seen in this bone assemblage can be explained only through use as a harness dog” and the dog’s use “to pull a travois or sled” (Millar 1978:365).

Among dogs from Initial Middle Missouri and Post Contact Coalescent period sites in the Middle Missouri sub-region of the Great Plains, Snyder (1995:212-216) found spondylosis deformans in the thoracic and lumbar vertebrae of several dogs, including an articulated unit with osteophytes occurring on the 13th thoracic through 4th lumbar vertebrae. In this same individual Snyder noted that the spinous processes of the thoracic region were “severely thickened” on the superior surfaces and the spinous processes of the 7th through 13th thoracic were “distinctly bent to the left.” Snyder suggested that these and other pathologies observed in dogs from the region “may well be related to chronic or intermittent stress to the vertebral column associated with travois pulling” (Snyder 1995:216).

At sites in Illinois and the Southeastern United States, Warren (2004) observed high frequencies of osteophytes and fractured spinous processes among prehistoric dogs. High frequencies of osteophytes were found in the first several thoracic, lower thoracic and lumbar vertebrae of these dogs. The author noted that the pattern of osteophyte distribution differed from that described in modern dogs by Morgan (1967) and attributed this to differences in mechanical stresses. She also found that at some sites, dogs buried with humans were more affected by spondylosis deformans than dogs recovered from middens. Among these dogs, high frequencies of spinous process fractures in the mid-thoracic, lower thoracic, and lumbar vertebrae were also observed. Warren (2004) suggested that the combination of these spinal pathologies may have been related to use of the dogs to carry packs.

It is important to keep in mind, as Morey (2010:98) noted, that the effects of pulling sledges are probably not directly comparable to those of pulling travois or carrying packs. Sledges are pulled by teams of multiple dogs attached to the sledge via harness and lines, whereas travois were harnessed directly to individual dogs at the shoulders. Packs, on the other hand, would have rested directly on the backs of individual dogs. Due to these differences in mechanics, sledges, travois, and packs likely differed in how they loaded the skeletons of individual dogs. Presumably these differing forces would impact dogs in a manner relative to the mode of transport employed. If this is the case, then we should expect the distribution of pathologies related to each mode of transport to differ as well.

Regardless of the complications raised by Morey (2010), the observations of Bellars (1969) and Bellars and Godsal (1969) have been repeatedly used to support the interpretation of lesions found in prehistoric dog materials as evidence of the use of dogs for transport. Osteoarthritis of the limbs, fractures of the distal scapula as well as spondylosis deformans affecting multiple contiguous vertebrae or patterns of vertebral involvement different from that observed in modern dogs, have specifically been suggested as possible indicators of the use of dogs for pulling travois or carrying packs (Snyder 1995:245-246; Warren 2004:212-213).

Additionally, it has been hypothesized that repetitive stress on the thoracic and lumbar vertebrae and associated supraspinous ligament may cause noticeably bent or flattened spinous processes. It is thought that such deformations may result from the developmental and cumulative lifetime pressure on this portion of the spine due to pulling travois, or more likely, carrying packs (Snyder 1995:212-213; Warren 2004:97-107). This interpretation is based entirely upon the observation of bent, fractured or compressed spinous processes in archaeological dogs from various sites (Albizuri et al. 2011; Arnold 1979; Millar 1978; Morey and Aaris-Sorensen 2006; Rossel et al. 2008; Snyder 1995; Warren 2004). Little veterinary literature presently exists on spinous process deformations in dogs or wolves. As such it remains impossible to assess the validity of claims that spinous process deformations are produced by animals habitually carrying loads on their backs.

Spondylosis deformans

Spondylosis deformans is a non-inflammatory spinal pathology associated with aging in dogs, humans, and many quadrupeds (Burt et al. 2013:57; Morgan et al. 1989:458; Morgan et al. 1967:57; Ortner and Putschar 1985:421). The disease is characterized by the formation of bony spurs called osteophytes at the margins of vertebral bodies which occur secondary to degeneration of the annulus fibrosus of the intervertebral disc (Burt et al. 2013:57; Morgan 1967a; Morgan 1967b:17; Morgan et al. 1967:57).

In dogs, other conditions may also cause the growth of marginal osteophytes and appear similar to spondylosis deformans. "Congenital vertebral deformities such as hemivertebrae, traumatic luxations or fractures, discitis or discospondylitis, or post-surgical instability can cause osteophyte production which attempts to bridge the disc space to re-establish stability" (Morgan et al. 1989:458). In these cases, osteophytes form secondary to injury and are separated clinically, despite similarities in morphology. In the past, disagreements regarding the specific pathogenesis of spondylosis deformans have resulted in the use of multiple terms to refer to the growth of marginal osteophytes (Morgan 1967a:7; Wright 1982:697). In dogs, spondylosis deformans has also been referred to as "spondylitis deformans traumatica, spondylitis ossificans deformans, spondylarthritis, anchylosing spondylitis, spondylosis deformans, spondylitis deformans, spinal osteoarthritis, morbus Bechterew, ankylosing spondylitis, syndesmitis ossificans, and spondylitis" (Morgan 1967a:7). Similarly, marginal osteophytes have elsewhere been referred to as a "bony spur, spondyle, or vertebral osteophyte" (Morgan 1967a:7).

Such inconsistent terminology is confusing and makes it difficult to identify spondylosis deformans cases in the literature. In the present study the term spondylosis deformans will be used to describe the non-inflammatory growth of marginal osteophytes as it relates to degeneration of the intervertebral disc. This differs from the previously mentioned congenital and traumatic conditions which also result in the growth of marginal osteophytes as well as the inflammatory process known as spondylitis which causes the articular facets and costovertebral joints to fuse (Ortner and Putschar 1985:421) but does not result in bridging vertebrae (Morgan et al. 1989:458; Morgan et al. 1967:57). The terms marginal osteophyte, or simply osteophyte, will also be used to describe the new bone growth that is characteristic of spondylosis deformans.

Identification and Appearance of Marginal Osteophytes

In cases of spondylosis deformans, the growth of marginal osteophytes originates at the junction of the vertebral endplate and the vertebral cortex, first growing outward from the cortex and then towards the intervertebral space and adjacent vertebrae (Burt et al. 2013:57; Morgan 1967b:17; Ortner and Putschar 1985:421). Though growth may extend beyond the margin of the vertebral border, marginal osteophytes do not affect vertebral endplates and never originate from these endplates (Morgan 1967a:25).

Marginal osteophytes on individual vertebra may be single or multiple in distribution and several vertebrae in an individual spinal column may be affected to various degrees (Morgan 1967a:7; Morgan et al. 1967:57). Osteophytes range in size from small spurs which do not extend beyond the vertebral endplate, to large finger-like projections which may, in severe cases, fuse with adjacent vertebra to form a bony bridge over the intervertebral disc space (Aufderheide and Rodriguez-Martin 1998:96; Burt et al. 2013:57; Morgan 1967a:7, 11-12; Ortner and Putschar 1985:421). The growth of osteophytes can cause the margins of the vertebral body to appear curved or lipped (Burt et al. 2013:57). Morgan (1967a:21) describes the general appearance of larger osteophytes as a "scoop" with the tip extending toward the intervertebral disc. The ventral or lateral surface is typically sloped and smooth and blends gently with the cortex of the vertebral body.

In dogs, osteophytes tend to develop on the ventral or ventro-lateral margins of vertebral bodies. Dorsal osteophytes are rare, except when they originate from the dorsal portion of the costal fovea. In these cases, dorsal osteophytes do not put pressure on the spinal cord and rarely project into the spinal canal or decrease the size of the intervertebral foramina (Morgan 1967a:21; Morgan 1967b:18). Osteophytes occur equally on the cranial and caudal vertebral margins (Morgan 1967a:56). In some cases, osteophytes appear on both cranial and caudal margins of the same vertebra and grow so large that they meet at the midpoint of the ventral surface (Morgan 1967b:19).

Etiology

In both dogs and humans, spondylosis deformans develops secondary to degenerative damage to the intervertebral disc, particularly in the annulus fibrosus (Aufderheide and Rodriguez-Martin 1998:96; Burt et al. 2013:57; Morgan 1967b:17; Morgan et al. 1989:457). In dogs, changes within the annulus fibrosus may then lead to focal lesions and intradiscal fissures which are associated with the formation of osteophytes (Morgan 1967a:57, 82). When the collagen that attaches the annulus fibrosus to the vertebral body is torn or separated from the vertebrae, the annulus fibrosus is prone to ventral displacement and stretching of the ventral longitudinal ligament which induces the formation of osteophytes (Thompson 2007:157). As the annulus fibrosus degrades, its ability to handle strain is decreased (Morgan 1967a:43). It is thought that the growth of marginal osteophytes may be the body's way of trying to stabilize the spine (Morgan et al. 1989:457). In advanced cases, the disc may degrade to the point at which little or no tissue is present, allowing the exposed bone of adjacent vertebrae to come into contact. This narrowing of the disc space seems to occur after the initial growth of marginal osteophytes (Morgan 1967a:57).

Growing osteophytes consist of new, woven bone. When an osteophyte has terminated growth, the woven bone is replaced by mature trabecular bone. It is not clear why some osteophytes grow to a larger size or to the point of fusion while others do not. Some osteophytes will cease to grow during earlier stages than others, and in some cases new osteophytes begin to form as others cease growth (Morgan 1967a:27-32). Larger osteophytes do not indicate "their earlier appearance in certain parts of the vertebral column" as compared to osteophytes of smaller size, and in general "the average size of osteophytes is similar throughout the vertebral column" of an individual (Morgan et al. 1967:64). It is interesting to note that in dogs, the size and shape of marginal osteophytes does not seem to correspond to the severity of disc degeneration (Morgan 1967a:57).

According to Thompson (2007:157), "The pathogenesis of spondylosis is believed to involve an *initial degenerative change in the ventral annulus fibrosus,* probably secondary to trauma." Morgan (1967a:82) compared the etiologies of spondylosis deformans in dogs, humans, domestic cats, and bulls. He found that patterns in the morphologic appearance and pathogenesis of osteophytes were very similar and speculated that "dynamic and mechanical factors are of importance in the pathogenesis of spondylosis deformans." In other words, a variety of factors may contribute to the development of marginal osteophytes in these animals. Other researchers have suggested that activity patterns, degenerative discs, trauma, or repeated pregnancies may play a role (Morgan 1967a).

Methods of Analysis

Spondylosis deformans has been studied in dogs and other animals with the use of radiography (Carnier et al. 2004; Langeland and Lingaas 1995; Morgan 1967b; Morgan et al. 1967; Morgan et al. 1989), scintigraphy (Meehan et al. 2009), necropsy, and the analysis of macerated vertebral columns removed from deceased animals (Harris 1977; Morgan 1967a, 1967b; Wright 1982). In most studies osteophytes are assessed macroscopically or with the use of a hand lens (Morgan 1967a; Morgan et al. 1967; Read and Smith 1968; Wright 1982). Though radiographic and scintigraphic methods allow for the analysis of living individuals, Morgan (1967a:53; 1967b:20) has shown that small osteophytes cannot be identified using these methods. Similarly, Morgan (1967b:18) stated that "radiographically, it was impossible to determine accurately the extent of osteophyte development at an intervertebral space." Studies in which macerated vertebral columns were evaluated not only provide a more accurate assessment of marginal osteophyte growth but also serve as better comparisons for archaeological materials. This is important to bear in mind, as much of the literature on spondylosis deformans in dogs and other animals is based upon radiographic studies of living animals and may underestimate the actual prevalence of the disease in a given population.

Regardless of the method used, the rate and severity of spondylosis deformans is assessed in all animals, including humans, using a basic scoring system. In most studies each intervertebral space is examined individually and given a score based upon the severity of the largest osteophyte present in the disc space. These scores correspond to predefined stages of severity with the lowest number corresponding to the absence of osteophytes or the earliest appearance of osteophytes, and the largest number representing osteophytes which have fused to adjacent vertebra (Carnier et al. 2004; Harris 1997; Jeffcott 1979, 1980; Kolmstetter et al. 2000; Langeland and Lingaas 1955; Lovell 1997; Meehan et al. 2009; Morgan 1967a, 1967b; Morgan et al. 1967, 1989; Wright 1982). For example, Morgan's (1967a:11-12) scale, which was based on Nathan's (1962) system for scoring the condition in humans, included the following stages:

- **Stage one** represented earliest gross findings, which were palpable nodules not identified on the macroradiographs. The changes were located over intervertebral spaces and adjacent vertebral rims and were up to 5 millimeters in diameter.

- **Stage two** consisted of small osteophytes on the vertebral margins. They were the earliest changes seen radiographically.

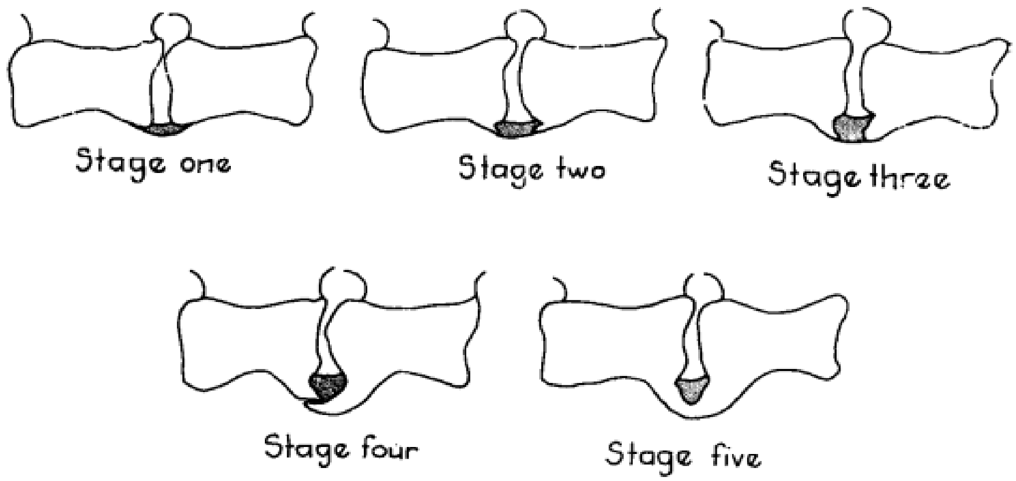
- **Stage three** was characterized by larger bony projections with a cup shape but without extension beyond the vertebral end plate.

- **Stage four** was identified by the tip of the osteophyte extending beyond the edge of the vertebral body ventrally and/or laterally. No union between opposing osteophytes was noted. Unattached crescent-shaped or triangular-shaped radiopaque segments found within ventral annular tissue were included in this category.

- In **stage five** bony fusion had occurred between opposing osteophytes.

This scoring scheme was illustrated by Morgan (1967a:12) and is presented above in Figure 3.1.

***Figure 3.1**: Five stages used by Morgan (1967a:12)*



Scoring of each vertebral space allows researchers to assess the rate and severity of spondylosis in an individual spinal column, in specific regions of a spinal column, or to compare rates within a population. In domestic dogs, these types of analyses have been used to identify general patterns of spondylosis deformans as well as predispositions for the disease.

Prevalence

Veterinary studies have shown that in general, dogs are affected by relatively high rates of spondylosis deformans. In a keystone study of spondylosis deformans in the domestic dog Morgan (1967a:52) found that 71 out of 116 (61%) individuals in a sample of various breeds were affected by marginal osteophytes on one or more vertebrae. In a similar study of 140 macerated dogs from England, Read and Smith (1968:161) found that 75% were affected with spondylosis deformans.

Morgan et al. (1967:59) studied spondylosis rates among dogs from England, the United States, and Sweden. The authors found that 110 of 175 (62.8%) dogs in the English sample, 48 of 206 (23.35%) dogs in the U.S. sample, and 36 of 223 (16.2%) dogs in the Swedish sample were affected by some degree of spondylosis deformans. In total 32% of the dogs in their study were affected by spondylosis deformans. However, in the English population macerated spinal columns were assessed whereas the samples from the United States and Sweden were studied radiographically. This difference in methodology may partially explain the much higher rates of spondylosis deformans in the English sample (Morgan et al. 1967:64), as small osteophytes are very difficult to identify radiographically (Morgan 1967a:53; Wright 1982:701).

For example, Wright (1982:699) radiographically analyzed 59 dogs and then extracted and macerated each specimen's spinal column. While radiograph analysis identified spondylosis in 17 out of 59 (28.8%) of the dogs, comparison to the macerated material demonstrated that this method only accurately identified 133 out a total of 194 osteophytes (Wright 1982:700). This means that only 68% of osteophytes could be identified using radiographs. Wright's (1982) study clearly indicates that radiographic studies of spondylosis in dogs underestimate the actual prevalence of the disease.

General Distribution

Studies show that in general, cervical vertebrae are less affected by spondylosis. The atlas (C1) and axis (C2) vertebrae appear to be unaffected (Read and Smith 1968:162; Morgan 1967a:18). When cervical osteophytes do occur they are typically of small size (stage 2 or less; Morgan 1967a:18).

Dogs affected by spondylosis deformans typically develop marginal osteophytes in the thoracic and lumbar portions of the vertebral column (Morgan 1967a; Read and Smith 1968; Wright 1982). Osteophytes in the thoracic region are most often stage 2 or 3 in severity, with fully fused vertebrae (stage 5) rare in this region (Morgan 1967a:18). Osteophytes in the lumbar vertebrae are most commonly stages 3 and 4. This is also the region where the highest frequency of stage 5 osteophytes has been observed (Morgan 1967a:18).

The most common pattern of osteophyte formation is one of low frequency from T3-T5 with a steady increase to a peaks at discs 15 (T8/T9) and 16 (T9/T10) and a subsequent decline to disc 25 (L5/L6), with an additional peak at disc 26 (L6/L7) (Morgan 1967a:18; Morgan et al. 1967:61; Read and Smith 1968:162). Peaks at disc 22 (L2-L3) and the lumbo-sacral articulation have been noted as well (Morgan et al. 1967:63; Wright 1982:701). Similarly, Read and Smith (1968:161) found peak values from the second to fourth lumbar vertebrae.

Individual dogs may be affected with marginal osteophytes at one or multiple intervertebral disc spaces (Morgan 1967a:7; Morgan et al. 1967:57). For example, in Morgan and colleagues' (1967:59) study of dogs in England, the United States, and Sweden the number of osteophytes "per affected vertebral column was respectively 9.3, 7.7 and 5.4." A correlation between increased age and the number of disc spaces affected with osteophytes has also been observed. Most studies present the average number of affected disc spaces by age group and this information will be discussed in the next section.

Predisposing Factors Contributing to the Development of Spondylosis Deformans

Research suggests that certain dogs may be more likely to develop spondylosis deformans than others. The growth of marginal osteophytes is known to increase with age and may also be more prevalent in certain breeds. It is not clear if there is a correlation between biological sex and spondylosis deformans, but there is some evidence that dogs of larger size/body mass are more likely to develop the disease.

Spondylosis deformans is associated with increased age in most species (Harris 1977:188; Kolmstetter et al. 2000:18; Morgan 1967a:8; Read and Smith 1968:162). Among dogs the number of individuals affected increases with age regardless of other predisposing factors (Carnier et al. 2004:86; Morgan 1967a:8; Morgan et al. 1967:62; Morgan et al. 1989:459; Read and Smith 1968:162). Morgan (1967a:54) has suggested that the onset of spondylosis in dogs tends to occur around 5-6 years of age (Morgan et al. 1967:62). In his research, the author found that about 50% of dogs between three and six years of age were affected with spondylosis deformans. By age nine, 75% had one or more marginal osteophytes, and nearly all dogs over age nine were affected. In a similar study the author suggested that nearly all dogs greater than 9 years of age were expected to be affected (Morgan et al. 1967:62). Similarly, Read and Smith (1968:162) reported that all dogs over the age of eleven showed signs of spondylosis deformans.

While a greater proportion of dogs develop spondylosis deformans with increased age this does not mean that the size or total number of osteophytes per dog also increases with age. In a random subsample of the total sample analyzed by Morgan (1967a:17), the author found that the average number of osteophytes found in dogs less than four years old was 3.5 per dog. For dogs age 4-10 years old the average was 10.66 per dog. In dogs over age ten the average number of osteophytes totaled 12.3 per dog. Statistical analysis showed that the difference in the number of osteophytes in dogs under four years old was significantly different compared to the other groups, but the differences between dogs aged four to ten, and dogs over ten did not differ significantly. Based on this result Morgan (1967a:54) suggested that the number of osteophytes does not necessarily continue to increase with age after they initially develop. Rather this result indicated that onset of spondylosis tends to occur during "middle age" (Morgan 1967a:54). This interpretation is further supported by the data presented by Morgan et al. (1967:62), which demonstrates an average age of onset of 5.8 years in female dogs, and 4.8 years in male dogs.

Just as increased age predisposes dogs to the development of spondylosis deformans, certain breeds have been found to have much higher rates of the disease than others (Morgan et al. 1967:56). Some breeds do not have higher rates of prevalence but instead have a tendency to develop larger, more severe osteophytes. Likewise, certain groups of breeds have been found to be less susceptible to developing osteophytes than others. These patterns suggest that in dogs, spondylosis deformans may have a heritable component.

Several studies have demonstrated the prevalence of spondylosis deformans among boxer dogs (Carnier et al. 2004:86; Langeland and Lingaas 1995:166; Morgan et al. 1967:55-56, 63). In a study of 851 purebred Italian Boxer dogs between the ages of 10-84 months, Carnier et al. (2004:86-88) found that 84% of all dogs were affected with marginal osteophytes. Of these dogs more than one third had three or more intervertebral disc spaces affected. Fifty percent of the dogs studied suffered from fused vertebrae due to marginal osteophyte formation. Morgan (1967a:55-56) also found that boxers had significantly higher numbers of osteophytes per individual vertebral column, and an overall higher frequency of severe (later stage) osteophytes.

Langeland and Lingaas (1995) studied spondylosis rates in boxer dogs to evaluate the possibility of a genetic link between the breed and the development of the disease. The authors studied 353 offspring from 24 randomly selected sires. They found that 91% of the total sample was affected by spondylosis deformans. This prevalence did not seem to be age related as 55% of yearling dogs were affected. Statistical heritability estimates based on this study indicated that there is a heritable, genetic predisposition for spondylosis deformans in boxers. It is not clear why this breed is affected at such high rates, though there appears to be a correlation between the presence of marginal osteophytes and dogs that suffer from hip dysplasia, a congenital disorder also known to affect boxers at high rates (Langeland and Lingaas 1995:166-168).

Like boxers, German shepherds have been shown to have higher rates of spondylosis, and are affected with more numerous and larger sized osteophytes per individual (Morgan 1967a:55-56). In addition to German shepherds, the cocker spaniel, Airedale terrier, and beagle all have been shown to have a relatively higher incidence of osteophytes than other breeds (Morgan et al. 1967:63). Standard poodles and dachshunds, however, seem to be affected at lower rates than other dogs (Morgan 1967:63).

Prevalence rates in the chondrodystrophoid breeds (described by Hansen (1952) as breeds that have "shown themselves to be particularly exposed to disc degeneration") have also been studied. Breeds in this group tend to be affected by chondrodystrophia, a condition that affects endochondral ossification and can cause achondroplasia of the limbs. This group includes breeds such as dachshunds and French bulldogs (Hansen 1952). Because these breeds commonly suffer from degeneration of the nucleus pulposus of the intervertebral disc at a young age they are of particular interest to studies of spondylosis deformans (Morgan 1967a:58). In a comparison of several breed groups Morgan (1967a:56) found that dachshunds were actually affected by fewer and smaller osteophytes than other groups, even when compared to older individuals. The author suggested that this result supports other findings that chondrodystrophoid breeds are less likely to develop spondylosis deformans than non-chondrodystrophoid breeds.

Commonly affected disc spaces were discussed in the previous section. While these findings represent general patterns observed in multi-breed studies it is important to note that patterns unique to specific breeds have also been observed. In other words, which intervertebral discs are affected and the degree to which they are affected may also be influenced by breed (Morgan et al. 1989:459).

It is not clear if biological sex plays a role in the development of spondylosis deformans. Most studies compare the prevalence among females to that of males, but there is no clear consensus as to whether one gender is more affected than the other (Morgan 1967a:8, 15 & 54).

The overall size of a dog may relate to the development of spondylosis. Morgan (1967a:16) assessed spondylosis prevalence between predefined weight classes. His analysis indicated that the prevalence of the disease increased relative to body weight. While the differences between weight classes were not significant overall, they were very close to statistical significance. However, it is important to note that the age distributions of dogs in each body weight class were not equal and this may have influenced the results (Morgan 1967a:55). Morgan et al. (1989:458) suggested that the frequent occurrence of spondylosis in beagle dogs may counter the idea that weight is a predisposing factor, but it is difficult to compare this result to other studies due to differences in methods and age distributions between studies.

Clinical Symptoms of Spondylosis Deformans

It is uncertain whether spondylosis deformans causes clinical symptoms in dogs. Carnier et al. (2004:85) suggested that the development of severe marginal osteophytes may cause "stiffness in the back, lameness, change of gait, and pain" but other sources have not found a link between outward symptoms and the disease (Bellars and Godsal 1969:35; Morgan 1967a:82; Morgan et al. 1967:65). Though Morgan et al. (1989:457) expressed uncertainty regarding clinical signs, the authors speculated that it is possible that marginal osteophytes might compress spinal nerve roots. They did not, however, believe this to be "a clinically important cause of vertebral pain or paresis" (Morgan et al. 1989:457).

Spondylosis Deformans in Other Non-Human Animals

Spondylosis deformans has been reported as a degenerative disease of aging in veterinary studies of a number of domestic and wild animals. The disease has been described in horses (Jeffcott 1980; Meehan et al. 2009), bulls (Baker and Brothwell 1980:131 citing other authors), wolves (Räikkönen et al. 2006, 2009), foxes, bears, hyenas (Harris 1977), and both domestic and wild felids (Kolmstetter et al. 2000; Read and Smith 1968).

There are few studies that specifically assess the prevalence of spondylosis deformans among wild wolves, but the disease has been reported in the species (Räikkönen 2006, 2009). Spondylosis deformans has been studied by Harris (1977) among wild foxes (*Vulpes vulpes*), which are also members of the canid family. Harris (1977) analyzed the prevalence of spondylosis deformans in 252 adult foxes from suburban London. The individuals were macerated and examined microscopically. Harris (1977) found that 34.5% of the sample was affected with marginal osteophytes to some degree. Unusually high rates were reported in young individuals, but a steady increase with age was also observed. Males seemed to be affected by more severe stages of osteophytes than females but not by a greater number of osteophytes overall, though the reasons for this difference are not known (Harris 1977:185, 190-192).

The pattern of osteophyte distribution differed among foxes as compared to dogs. Whereas dogs are affected by very low rates of osteophytes in the cervical vertebrae, foxes were affected in all spinal regions including the caudal vertebrae, though severity of osteophytes was shown to increase in the lumbar and sacral regions (Harris 1977:185-190).

The most relevant of these studies are those pertaining to horses and canids, as these relate most directly to load bearing among domestic dogs. Since very little information is available on the rates of spondylosis deformans in sled dogs or other dogs used to pull or carry burdens, horses used for riding offer the closest proxy. Modern riding horses have been shown to be most affected by spondylosis deformans at discs between the 9th thoracic and the 2nd lumbar vertebrae, often with involvement in multiple contiguous vertebrae (Jeffcott 1980:204; Meehan et al. 2009:804). These results are in contrast to Wells (1972 cited in Baker and Brothwell (1980:131)) who suggested that modern riding horses are most affected in the lumbar region, whereas prehistoric wild horses were most affected in the thoracic region.

It is interesting to note that modern riding horses are affected by relatively low rates of spondylosis when compared to the rates observed in modern dogs. In a study of 244 horses, Jeffcott (1980:204) found that only 14, or 5.7% showed the presence of marginal osteophytes on a radiograph. Meehan et al. (2009:803) used radiographic and scintigraphic image analyses of 670 horses and found that 23 individuals, or 3.4% were affected. However, Meehan and colleagues (2009) also pointed out that a separate study of 23 macerated vertebral columns demonstrated a prevalence of 36%, suggesting that radiographic methods underestimate the prevalence of the disease in horses (Meehan et al. 2009:805).

Though this latter number indicates that as many as one in three riding horses may be affected, it is not clear if spondylosis rates can be directly related to carrying weight upon the horse's back, as these rates have not been compared to those seen among horses not used for riding. When compared to the rates observed in dogs by Morgan (1967a) and other authors (Carnier et al. 2004; Langeland and Lingaas 1995; Morgan et al. 1967, 1989; Read and Smith

1968), a 36% involvement among horses does not seem that unusual, or even that high, relatively speaking.

In archaeological studies spondylosis deformans has been used as an indicator that horses were ridden during their lives, but support for this correlation in modern riding horses is unclear (Levine 2005; Levine et al. 2000). Arguing that marginal osteophytes indicate riding among Iron Age Scythian horses, Levine et al. (2000:129) stated that “It is generally believed that riding also causes or contributes to their development.” The authors, one of whom is veterinarian Leo Jeffcott, cite Jeffcott (1979) as evidence in support of this assertion. After thoroughly reading Jeffcott (1979), however, I found no such statement linking osteophyte formation to riding. Furthermore, this study, which evaluated the prevalence of spondylosis deformans and other diseases in 110 riding horses, reported that no evidence for spondylosis was found in any of the individuals assessed (Jeffcott 1979:143). Meehan et al. (2009) also has presented some evidence of prevalence rates of spondylosis deformans in horses, but again it is unclear if their formation is specifically tied to being ridden. Overall, it is not clear if horses develop spondylosis deformans as a result of carrying riders or if they are prone to the disease for other reasons, such as living to advanced age.

Levine et al. (2000:129) compared the rate of spondylosis in Iron Age horses buried with saddles to that observed by the authors in a sample of eight modern, free-living adult ponies that were never ridden. This study showed that 1 in 8 ponies was affected, a prevalence of 12.5%, and that age was not a factor. In the archaeological sample, 3 out of 4 (75%) horses were affected. The authors interpreted the higher rate of spondylosis in the Iron Age horses as an indicator of carrying riders (Levine et al. 2000:128-129). Clearly sample sizes used in this study were too small to demonstrate a statistically significant correlation between spondylosis and carrying riders. Furthermore, little is known about the life histories of the archaeological horses used for comparison. Though the observations of Levine (2005) and colleagues (2000) are interesting, the evidence does not clearly support a relationship between marginal osteophyte development and the carrying of riders.

Spinous Process Deformities

Veterinary literature regarding deformations of vertebral spinous processes in dogs is scarce. For this reason, the etiology behind deformations in the angle or shape of these elements is not well understood. However, it is reasonable to suspect that certain factors may contribute to such lesions. Fractures not properly set can lead to misalignment of the element during the healing process. If adequate time passes between the initial injury and the time of death, extensive remodeling of the bone may make it difficult or impossible to positively identify the fracture in dry bone. In such cases deformity of shape may be the only indication that a fracture occurred (Roberts and Manchester 2005:92; Warren 2004:93).

It is also possible such deformities occur during the process of growth and development. Genetic or disease processes could potentially contribute to deformations at the time of bone formation in utero, or during the ossification of the vertebra during the juvenile period. Similarly, if the spine was habitually subjected to significant pressure during the growth and development phase, this might also cause irregular growth or alteration in shape of the spinous processes.

Based upon studies of archaeological dogs, Lynn Snyder (1995:213) has hypothesized that the deformation of spinous processes is related to the supraspinous ligament which runs along the top of the spinous processes and connects to muscles which strengthen the spine.

Snyder (1995:213) suggested that when this ligament experiences stress, it can cause the underlying spinous processes to bend or flatten.

Deformations of the spinous processes, specifically those that are bent, fractured or appear dorsally compressed, have been described in archaeological dog specimens in many parts of the world. These deformities have been reported among dogs in regions including the Arctic (Arnold 1979; Morey and Aaris-Sorensen 2002), the Great Plains (Snyder 1995) and Southeast (Warren 2004) regions of the United States, southern Siberia (Losey et al. 2011:182), and the Iberian Peninsula (Albizuri et al. 2011).

It is interesting to note that the condition also has been described in a set of 10 donkey skeletons found buried in a pharonic mortuary complex in Abydos, Egypt. The specimens, dating to about 5,000 years of age, are the oldest recovered donkey specimens to date. The authors have suggested that the spinous process deformities observed in these specimens might have resulted from carrying loads or human riders (Rossel et al. 2008:3719).

Skeletal Indicators of Dog Transport: Methodological Challenges and Research Questions

The relationship between spondylosis deformans and load pulling or carrying has never been systematically evaluated using dogs of known life history. Similarly, there are no known collections of skeletal dogs used for pulling travois or carrying packs, making it impossible to systematically evaluate the relationship between these activities and any of the skeletal indicators that have been proposed by archaeologists. Though Bellars and Godsal (1969) assessed the occurrence of the disease among eleven huskies used by the British Antarctic Survey, they did not statistically evaluate the rate of spondylosis deformans in these sledge dogs compared to the rates seen among dogs not used for this purpose.

As described earlier, spondylosis deformans in dogs is also known to be influenced by a number of factors including age, breed, and size. If there is also a correlation between load bearing or pulling and spondylosis deformans in these animals, it may be difficult to rule out these other contributing factors, especially when the condition is examined by occurrence rate alone. Both Warren (2004) and Snyder (1995) report archaeological dog specimens with osteophytes in multiple consecutive vertebrae in the thoracic and lumbar regions. While modern dogs are most affected in these same regions, veterinary reports do not mention the prevalence of osteophytes affecting multiple contiguous vertebrae in such dogs. In other words, past studies do not provide results for individual dogs, but rather provide rates for total number of specific vertebrae affected. Patterning in affected vertebrae when reported by individual therefore may provide an important indicator of the etiological cause of specific pathologies present in affected vertebrae.

Veterinary reports do not describe the occurrence or rate of occurrence of bent, flattened or otherwise disfigured spinous processes in modern dogs. If deformities of the spinous processes are related to the use of dogs for pulling or carrying burdens, then we would not expect such deformations to be common in modern dogs not used for pulling or hauling loads. Similarly, if these patterns are related to load bearing then we should not expect to see these deformations in wild wolves, the species most genetically and morphologically similar to domestic dogs.

To evaluate these hypotheses, the spinal columns from a large sample of domestic dogs and wild wolves will be assessed to address the following research questions:

1. At what rate does spondylosis deformans occur among modern wolves and in modern dogs that did not pull or haul loads?
2. At what rate are modern dogs and wolves affected with marginal osteophytes on multiple contiguous vertebrae?
3. Is spondylosis deformans a reliable indicator of load bearing in dogs or more likely a product of natural variation, ageing, or genetic causes?
4. At what rate do bent or deformed spinous processes occur among modern wolves and dogs not used for traction?
5. Are bent, flattened, or fractured spinous processes a reliable indicator of load bearing in dogs?

Chapter 4 : Materials and Methods

The skeletal remains of 396 modern dogs and wolves were assessed to evaluate the rates and patterns of spondylosis deformans and the occurrence of bent spinous processes. The occurrence of fractured ribs was also recorded to evaluate the relationship between trauma and these spinal pathologies. Skeletal remains were housed in seven different museum collections in North America and Europe.

A total of 155 dogs were assessed. The sample was comprised of 61 females and 69 males. The dog specimens were housed at the following seven museums: 1) the University of Alberta Zooarchaeological Reference Collection, Edmonton, Canada; 2) the University of Alaska Museum of the North, Fairbanks, USA; 3) the Smithsonian Institution Division of Mammals, Washington D.C., USA; 4) the California Academy of Sciences, San Francisco, USA; 5) the American Museum of Natural History, New York; 6) the University of Nebraska State Museum, Lincoln, USA; 7) the Natural History Museum of Bern, Bern, Switzerland.

Individuals were identified as male or female based upon museum records or the presence of a baculum (*Os penis*). Specimens of unknown sex without a baculum were not assumed to be female but were instead classified as unknown. Similarly, the age of each individual was determined through museum records or fusion of long bone epiphyses. Because domestic dogs are considered physically mature by one year of age individuals were considered juvenile if listed as one year of age or less, or if the epiphyses of the long bones were unfused.

The dog sample included both modern sled dogs (n=19) and dogs never used for load bearing or carrying activities (n=125) as well as wild (n=5) and captive (n=6) dingoes (*Canis lupus dingo*), a subspecies of wild dog found in Australia (a detailed breakdown of all groups is

Table 4.1: *Dogs Assessed*

	All Groups	Non- transport Dogs	Wild Dingoes	Captive Dingoes	Sled dogs
Female	61	54	2	1	4
Male	69	55	2	5	7
Unknown	25	16	1	0	8
Adult	149	121	4	5	19
Juvenile	6	4	1	1	0
Total	**155**	**125**	**5**	**6**	**19**

provided in Table 4.1). Life history information was available for all specimens, though the amount of information available varied for each. In total, 61 females, 69 males, and 25 individuals that could not be identified to sex were assessed. This sample included 149 adults and 6 juveniles.

The non-transport dog sample (n=125) included 55 males, 54 females, and 16 dogs that could not be identified to sex (Table 4.1). One hundred-six dogs from 57 different breeds were represented as well as 19 individuals of unknown breed. Individuals of known breed were sub-categorized into three size groups used and created by the American Kennel Club and Federation Cynologique Internationale standard for each breed (http://www.akc.org/dog-breeds/; http://www.fci.be/en/Nomenclature/). These size groups included 29 small dogs, 32 medium dogs, and 45 large dogs. For a list of breeds studied and their relative size group see Appendix 1.

A total of 241 North American and Scandinavian gray wolves were assessed using specimens housed in five different museum collections. These collections are: 1) the Royal Alberta Museum in Edmonton, Canada; 2) the University of Alaska Museum of the North, Fairbanks, USA; 3) the Smithsonian Institution Division of Mammals; Washington D.C., USA; 4) the California Academy of Sciences, San Francisco, USA; 5) the Swedish Museum of Natural History, Stockholm, Sweden.

Table 4.2: Wolves Assessed

	All	Wild	Captive	Inbred	Non-Inbred
Female	103	99	4	35	68
Male	124	117	7	44	80
Unknown	14	12	2	2	12
Adult	167	155	12	58	109
Juvenile	74	73	1	23	51
Total	**241**	**228**	**13**	**81**	**160**

The wolf sample was comprised of 103 female and 124 male wolves. Fourteen individuals were not identified to sex. In total, 167 mature adults and 74 juveniles were represented (Table 4.2). The sample included both wild (n=228) and captive (n=13) individuals. It also included a population of highly inbred wolves from Sweden (n=81). Grey wolf populations were severely reduced in Sweden in the mid-20th century with less than 10 individuals present by the early 1970's when they were given legal protection by the Swedish government. In 1983 a mating pair successfully gave birth to a litter and helped to re-establish the modern population of grey wolves living in Sweden today. The population is known to have low genetic variability due to high rates of inbreeding (Räikkönen et al. 2006:65-66).

Little life history information is available for the wild wolf sample though some information is available for captive individuals. Age of death information for the Swedish population was determined by the museum through assessment of dental cementum bands (personal communication with Daniela Kalthoff, Mammal Curator, Swedish Museum of Natural History, September 2015). For the Alaskan population, age of death was estimated based upon epiphyseal fusion.

All individuals were assessed for both spondylosis deformans and the occurrence of bent spinous processes as well as fractured ribs, in order to identify possible incidences of trauma. For each individual, all available vertebrae from the first cervical to the seventh lumbar vertebra were identified and examined. Missing vertebrae that could not be analyzed were noted. All elements with spondylosis deformans, deformed spinous processes, fractured ribs or other unusual lesions were photographed to provide a secondary record of all observed pathologies.

Rib fractures were recorded by noting the presence or absence of fractures in an individual. In individuals with rib fractures, all ribs were identified to side and to number based upon the relative size, shape, and position of the rib heads and ends. Fractures were recorded by specific rib with notes detailing the location of the break and degree of remodeling.

The presence of spondylosis deformans was evaluated using methods developed by human osteologists and veterinarians. For all specimens, each vertebrae of the spinal column from the cervical vertebrae (C1-C7), thoracic vertebrae (T1-T13), and lumbar vertebrae (L1-L7) was evaluated. The 3 sacral vertebrae and ~20 caudal vertebrae were not assessed. The presence or absence of spondylosis was recorded for both the cranial and caudal surfaces. Where spondylosis was present, the severity of the growth was classified with a number following the scoring system developed by Carnier et al. (2004) and illustrated in Plates 4.1-4.3 below:

> Grade 1 = small osteophytes placed on the edge of the epiphysis were observed, but did not exceed the vertebral edge
>
> Grade 2 = osteophytes were enlarged beyond the edge of the epiphysis, but did not connect to osteophytes on the opposite vertebra
>
> Grade 3 = osteophytes placed on adjoining vertebrae connected one to each other, thus establishing an appreciable bony spur

Plate 4.1: Example of Grade 1 Osteophytes

Plate 4.2: Examples of Grade 2 Osteophytes

Plate 4.3: Examples of Grade 3 Osteophytes

To assess the occurrence of bent spinous processes, the angle of the spinous process of each vertebra was measured with a protractor (Plate 4.4). Spinous processes are normally oriented perpendicular to the vertebral body at a 90-degree angle. Any spinous process inclined to the right or left by more than 10 degrees (angle of process $\leq$80 or $\geq$110 degrees) was considered bent with the direction and location of the angle noted. To describe the location of the bend, the spinous process was visually divided into thirds. Processes bent in the upper or dorsal third were coded as D (distal), the middle third as C (central), and those in the lower third closest to the vertebral body were coded as P (proximal) (Plate 4.5).

Unusually flattened or compressed spinous processes were noted with specific descriptions of the anomaly provided. As bending of the spinous processes may be related to fracture and subsequent remodeling of the process, any evidence of ante mortem fracture was

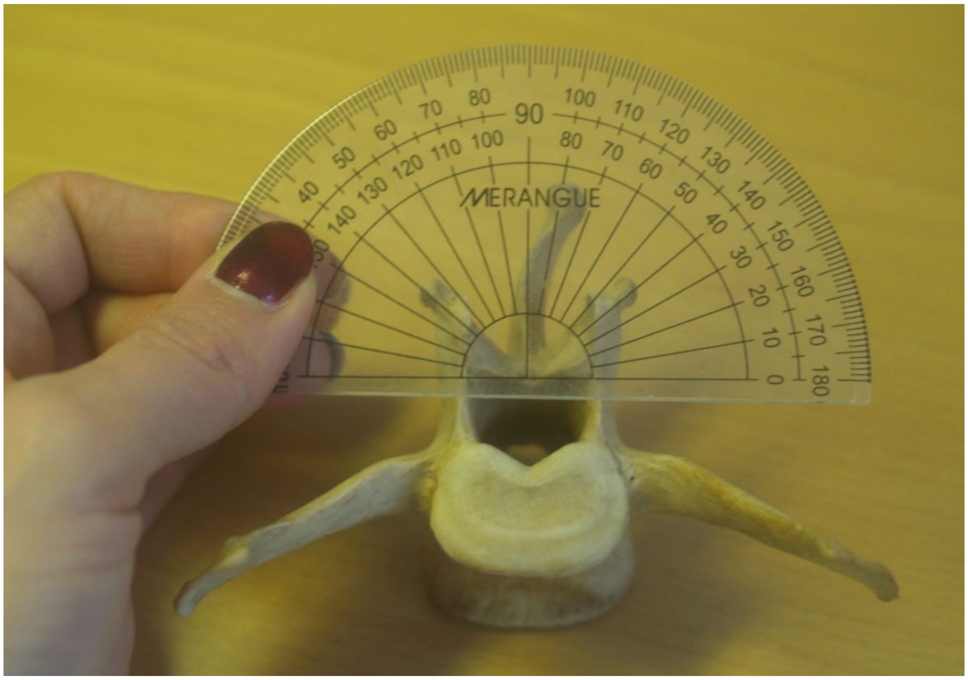


Plate 4.4: Measurement of the bent spinous process angle with protractor

Plate 4.5: Example of a bent spinous process coded BLC (bent left central)

recorded using the same coding system employed for recording the location of bending in the processes. Processes absent due to fracture were also noted and the fracture assessed as ante-mortem or post-mortem based upon evidence of subsequent remodeling.

Statistical analyses were performed to compare frequencies of the spinal pathologies of interest between the different study groups, as well as for comparing the frequencies of various manifestations of these pathologies within individual groups. Simple frequency comparisons were made using the Pearson's Chi-squared Test for larger sample sizes and Fisher's Exact Test for smaller sample sizes of five individuals or less. All statistical analyses were performed using Microsoft Excel 2016.

Chapter 5 : Results

Spondylosis Deformans

Incidence and distribution: Osteophytes were found at the margins of vertebral endplates in many locations, indicating the presence of spondylosis deformans. Osteophytes appeared as single or multiple spurs arranged around the ventral and lateral edges of the caudal or cranial endplate. Spurs ranged in size from a few millimeters to large scoop shaped projections. In some cases, osteophytes formed a large bridge that came in contact with or was completely fused to the adjacent vertebral endplate. The size of osteophytes on one endplate did not always correspond to the size of osteophytes on the adjacent vertebral surface. However, in many cases where large stage 2 osteophytes extended toward or even made contact with the adjacent vertebral endplate, osteophytes were smaller on the latter surface, perhaps inhibited by the invasive osteophyte growth from the adjacent vertebra. The presence of osteophytes on one vertebral endplate did not always co-occur with osteophytes on adjacent endplates. Similarly, the presence of osteophytes on the cranial endplate did not guarantee the presence of osteophytes on the caudal endplate or vice versa. However, in some cases osteophytes appeared on both, and at times grew together to form a continuous bony bridge between the cranial and caudal surfaces of an individual vertebra.

Dogs were affected with spondylosis deformans at relatively high rates, regardless of their use in transport activities (for a detailed comparison of rates see Table 5.1). The frequency of osteophytes in non-transport dogs was 90/136 individuals (66.18%). When dingoes were

Table 5.1: Spondylosis deformans in dogs and wolves and percentage of individuals affected: a) dogs, b) wolves

5.1a.

	All Non-transport dogs	Dogs w/o Dingoes	All Dingoes	Captive Dingoes	Wild Dingoes	Sled Dogs
	(n=136)	(n=125)	(n=11)	(n=6)	(n=5)	(n=19)
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Female	42/57(73.68)	42/54(77.78)	0/3(0.00)	0/1(0.00)	0/2(0.00)	3/4(75.00)
Male	42/62(67.74)	39/55(70.91)	3/7(42.86)	3/5(60.00)	0/2(0.00)	7/7(100.00)
Unknown	6/17(35.29)	5/16(31.25)	1/1(100.00)	0/0(0.00)	1/1(100.00)	2/8(25.00)
Adult	90/130(69.23)	86/121(71.07)	4/9(44.44)	3/5(60.00)	1/4(25.00)	12/19(63.16)
Juvenile	0/6(0.00)	0/4(0.00)	0/2(0.00)	0/1(0.00)	0/1(0.00)	0/0(0.00)
Total	**90(66.18)**	**86(68.80)**	**4(36.36)**	**3(50.00)**	**1(20.00)**	**12(63.16)**

5.1b.

	All Wolves	Wild Wolves	Captive Wolves	Inbred Wolves	Non-inbred Wolves
	(n=241)	(n=228)	(n=13)	(n=81)	**(n=160)**
	n (%)	n (%)	n (%)	n (%)	n (%)
Female	17/103(16.50)	13/99(13.13)	4/4(100.00)	9/35(25.71)	8/68(11.76)
Male	30/124(24.19)	25/117(21.37)	5/7(71.43)	12/44(27.27)	18/80(22.5)
Unknown	4/14(28.57)	3/12(25.00)	1/2(50.00)	1/2(50.00)	3/12(25.00)
Adult	51/167(30.54)	41/155(26.45)	10/12(83.33)	22/58(37.93)	29/109(26.61)
Juvenile	0/74(0.00)	0/73(0.00)	0/1(0.00)	0/23(0.00)	0/51(0.00)
Total	**51(21.16)**	**41(17.98)**	**10(76.92)**	**22(27.16)**	**29(18.13)**

removed from this group the frequency was 86/125 (68.80%). The overall frequency of affected dingoes was 4/11 (36.36%), with a frequency of 3/6 (50%) in captive dingoes and 1/5 (20%) in wild dingoes. The frequency of affected sled dogs was 12/19 (63.16%). Though non-transport dogs were affected with spondylosis deformans at a higher frequency than sled dogs, the differences between the two groups were not significant and most likely due to chance (X^2=0.08, p=0.6231).

The frequency of spondylosis deformans for wolves as a group was 51/241 (21.16%). In this group captive wolves had a significantly higher incidence of the disease than wild wolves (p=<0.0001). Specifically, captive wolves were affected at a frequency of 10/13 (76.92%) whereas the frequency among wild wolves was 41/228 (17.98%). The frequency among the Swedish population of inbred wolves was 22/81 (27.16%). For non-inbred wolves the frequency was 29/160 (18.13%). Though the inbred population did not differ from the non-inbred group at a statistically significant level it is important to note that the two groups differed at a level close to being statistically significant (X^2=2.07, p=0.1048). These results suggest that there is a ~90% chance that the differences observed between the inbred population and non-inbred population did not occur randomly.

Overall, wolves were affected with spondylosis deformans at a much lower rate than either of the dog groups. Statistically significant differences were found when the wolf group was compared to the non-transport dog group (X^2=49.9007, p=<0.0001) and when compared to the sled dog group (X^2=12.8420, p=<0.0001).

Rib fractures: The occurrence and number of healed and unhealed fractured ribs was recorded for each individual. This was done to identify any patterns in the occurrence of fractured ribs and the development of spondylosis deformans in the spine. These data are presented in Table 5.2 below. Among non-transport dogs, 7/132 (5.30%) individuals suffered from one or more fractured ribs. Of these individuals 4/7 (57.14%) were also affected with spondylosis deformans. Notably, however, only 4/88 (4.55%) non-transport dogs with spondylosis deformans also had fractured ribs.

Among sled dogs 4/18 (22.22%) individuals suffered from one or more rib fractures. Of these individuals 2/4 (50.00%) were also affected with spondylosis deformans, though only 2/12 (16.66%) of all individuals affected by spondylosis deformans also had rib fractures.

Table 5.2: Occurrence of spondylosis deformans and rib fractures in dogs and wolves by frequency and percentage of affected individuals

	Non-transport Dogs	**Sled Dogs**	**Wolves**
	(n=132)	(n=18)	(n=240)
	n (%)	n (%)	n (%)
Spondylosis Deformans	88/132(66.67)	12/18(66.67)	50/240(20.83)
Rib Fractures	7/132(5.30)	4/18(22.22)	56/240(23.33)
Both Rib Fractures & Spondylosis Deformans	4/132(3.03)	2/18(11.11)	19/240(7.92)

Wolves were the most affected by rib fractures with 56/240 (23.33%) individuals suffering from one or more fractured ribs. Of these individuals 19/56 (33.93%) also suffered from spondylosis deformans. Overall 19/50 (38.00%) of all individuals affected by spondylosis deformans were also affected with rib fractures.

Sex: Among non-transport dogs the incidence of spondylosis deformans was higher in females with a frequency of 42/57 (73.68%) compared to 42/62 (67.74%) in males (Table 5.1). The frequency was 6/17 (35.29%) for individuals of unknown sex. When dingoes were removed from this group the frequency for females was 42/54 (77.78%), for males 39/55 (70.91%), and for individuals of unknown sex was 5/16 (31.25%). No cases of spondylosis deformans were observed among the three female dingoes analyzed. The frequency for male dingoes was 3/7 (42.86%) overall, with a frequency of 3/5 (60.00%) in captive dingoes, but obviously the number of specimens under consideration here is quite small. No male wild dingoes were affected 0/2 (0.00%), and the one wild dingo of unknown sex was affected (frequency 1/1 (100.00%)). The frequency among female sled dogs was 3/4 (75.00%) whereas all male sled dogs were affected (7/7 (100.00%)). The sled dogs of unknown sex were affected at a frequency of 2/8 (25.00%) individuals.

Female wolves were affected with spondylosis deformans at a frequency of 17/103 (16.50%) (Table 5.1). This was lower than the frequency in males, which was 30/124 (24.19%). Wolves of unknown sex were affected at the highest rate of frequency at 4/14 (28.57%). When wild wolves are separated from the captive wolves, wild females were affected at a rate of 13/99 (13.13%) while all captive females were affected (4/4 (100.00%)). Male wild wolves were affected at a frequency of 25/117 (21.37%) whereas the rate among captive males was 5/7 (71.43%). For wild individuals of unknown sex, the frequency was 3/12 (25.00%) as compared to their captive counterparts where the incidence was 1/2 (50.00%). When the group is divided into inbred versus non-inbred wolves, inbred females were affected at a frequency of 9/35 (25.71%) compared to non-inbred females where the frequency was 8/68 (11.76%). In male inbred wolves the frequency was 12/44 (27.27%) compared to non-inbred males, which were affected at a lower rate of 18/80 (22.5%). Among inbred individuals of unknown sex ½ (50.00%) were affected as compared to a frequency of 3/12 (25.00%) in non-inbred individuals of unknown sex.

Age: In all groups, spondylosis deformans was only found in physically mature individuals—no juvenile individuals were affected with the pathology (Table 5.1). In non-transport adult dogs, the frequency was 90/130 (66.18%). When dingoes were removed from this group the frequency increased to 86/121 (71.07%). The frequency among adult dingoes was 4/9 (44.44%), with captive adult dingoes (3/5 (60.00%)) affected at a higher frequency than wild adult dingoes 1/4 (25.00%). No juvenile sled dogs were studied, and the frequency among adults was therefore the same as the frequency for the whole group at 12/19 (63.16%).

Table 5.3: Spondylosis deformans in dogs and wolves by age group and percentage of individuals affected

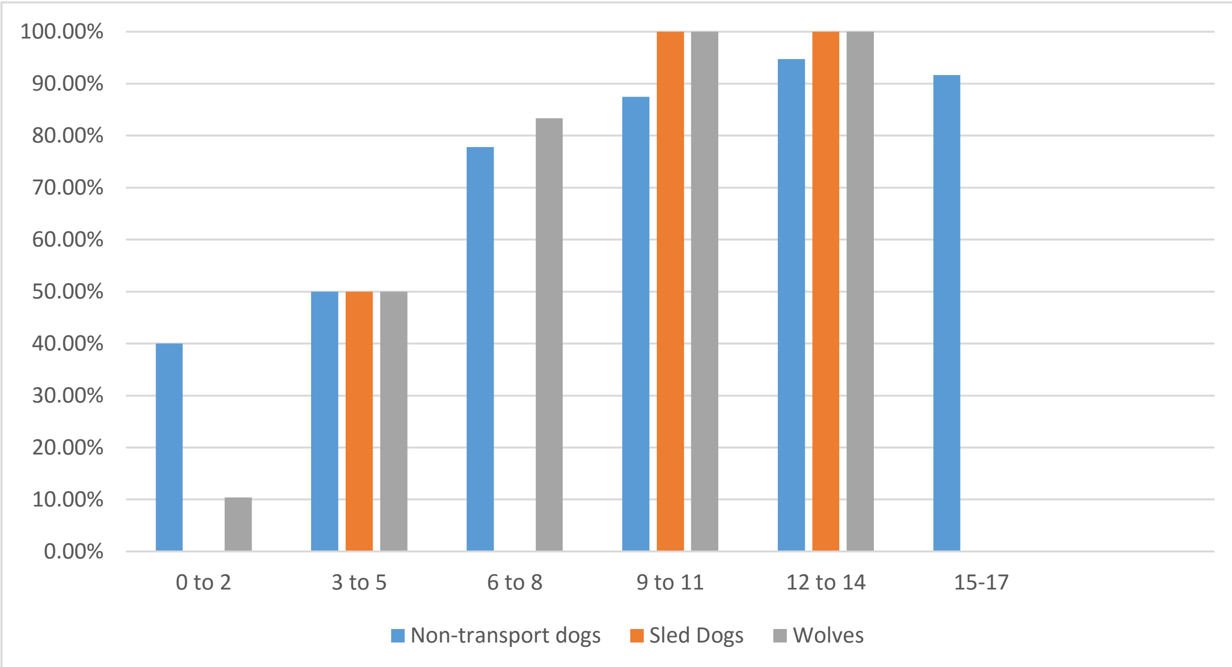
Age range (years)	Non-transport dogs	Sled dogs	Wolves
	(n=77)	(n=10)	(n=70)
	n (%)	n (%)	n (%)
0-2	2/5(40.00)	N/A	5/48(10.42)
3-5	4/8(50.00)	1/2(50.00)	6/12(50.00)
6-8	7/9(77.78)	N/A	5/6(83.33)
9-11	21/24(87.50)	6/6(100.00)	3/3(100.00)
12-14	18/19(94.74)	2/2(100.00)	1/1 (100.00)*
15-17	11/12(91.67)	N/A	N/A
Total	**63(81.82)**	**9(90.00)**	**20(28.57)**

***captive individual**

Overall, 51/167 (30.54%) adult wolves were affected. Wild adults were affected at a rate of 41/155 (26.45%) and captive adults at a much higher rate of 10/12 (83.33%) (Table 5.1). When divided into the inbred and non-inbred wolf groups, inbred adults were affected at a rate of 22/58 (37.93%) compared to a frequency of 29/109 (26.61%) in non-inbred adults.

When individuals of known age were separated into discrete age groups there was a consistent increase in the frequency of spondylosis with age in all groups (non-transport dogs, sled dogs, and the wolves). Age group data is presented in Table 5.3 above. Among ages zero to two years-old 2/5 (40.00%) non-transport dogs were affected, whereas 5/48 (10.42%) wolves were affected. In individuals ages three to five 4/8 (50.00%) non-transport dogs, 1/2 (50.00%) sled dogs, and 6/12 (50.00%) wolves were affected. Among individuals ages six to eight 7/9 (77.78%) non-transport dogs and 5/6 (83.33%) wolves were affected. For individuals ages nine to eleven 21/24 (87.50%) non-transport dogs and all (100%) sled-dogs (6/6) and wolves (3/3) were affected. Similarly, among those ages twelve to fourteen 18/19 (94.74%) non-transport dogs and all sled dogs (2/2) and all wolves (1/1) were affected. Among non-transport dogs ages fifteen to seventeen 11/12 (91.67%) were affected.

Figure 5.1: Spondylosis deformans in dogs and wolves of known age groups



The rise in the frequency of individuals affected by spondylosis deformans as age increased was a consistent pattern across all groups. This can also be examined by using broader age categories. For example, among both non-transport dogs and wolves, the frequency of affected individuals under five years of age, and those six years of age or older differed significantly (Non-transport dogs, X2=2.43, p=0.0003; Wolves, X2=15.41, p=<0.0001). Note that this could not be demonstrated in the sled dog group as the sample is too small to make a meaningful comparison.

Breed group**:** When non-transport dogs were divided into size-related breed groups the proportion of individuals affected by spondylosis deformans steadily increased as body size increased **(**Table 5.4**)**. Small dogs were least affected, with a frequency of 16/29 (55.17%). The frequency in medium dogs was 28/43 (65.12%) and in large dogs was 41/45 (91.11%). While the frequencies of spondylosis deformans in small and medium dogs were not significantly different

Table 5.4: Spondylosis deformans in non-transport dogs by size and percentage of individuals affected

	Small	**Medium**	**Large**
	(n=29)	(n=43)	(n=45)
	n (%)	n (%)	n (%)
Females	10/16(62.50)	13/19(68.42)	18/19(94.74)
Males	6/12(50.00)	14/22(63.64)	18/20(90.00)
Unknown	0/1(0.00)	1/2(50.00)	4/6(66.67)
Total	**16(55.17)**	**28(65.12)**	**41(91.11)**

(X^2=0.28, p=0.3959), the differences between small and large breeds (p=0.0005) and between medium and large breeds (p=0.0040) were highly significant. In all of the breed groups females were affected by higher rates of spondylosis deformans than males, but this difference was not significant in any breed size and was likely due to chance.

Number of affected endplates: The total number of endplates with osteophytes varied greatly between affected individuals. In non-transport dogs, affected individuals were found to have anywhere from 1- 44 endplates with spondylosis deformans. Affected females had an average of 18.50 affected endplates per individual (see Table 5.5). Affected males had an average of 14.40 affected endplates per individual and affected individuals of unknown sex had an average of 14.33 affected endplates per individual. Overall, non-transport dogs had an average of 16.31 affected endplates per affected individual.

Individual sled dogs were affected with fewer osteophytes than non-transport dogs. Sled dogs had anywhere from 1-27 endplates per individual affected. Affected female sled dogs had an average of 3.50 endplates with osteophytes, affected males an average of 11.86 endplates, and the average for affected individuals of unknown sex was 4.00 endplates. Overall, sled dogs had an average of 8.08 endplates with spondylosis deformans per affected dog.

Table 5.5: Average number of endplates affected with spondylosis deformans in dogs and wolves

	Non-transport Dogs	Sled-Dogs	Wolves
	(n=89)	(n=12)	(n=51)
Female	18.50	3.50	10.06
Male	14.40	11.86	7.33
Unknown	14.33	4.00	15.00
Total	**16.31**	**8.08**	**8.80**

Wolves with spondylosis deformans were affected with osteophytes on anywhere from 1-45 endplates per individual. Females with the disease had an average of 10.06 affected endplates in their spinal columns. Males were less affected with an average of 7.33 affected endplates per individual. Wolves of unknown sex had an average of 15 affected endplates per individual. Overall, wolves affected with spondylosis deformans had an average of 8.8 affected endplates per individual.

Multiple Contiguous Vertebrae: In this study, multiple contiguous vertebrae were defined as the presence of 3 or more consecutive vertebrae with spondylosis deformans on one or both endplates. Multiple contiguous affected vertebrae were found in specimens from all groups (Table 5.6). In non-transport dogs 64/90 (71.11%) individuals had multiple contiguous vertebrae affected. The average number of contiguous vertebrae affected was 8.89. Eight of the 90 individuals (8.89%) with spondylosis deformans had an entire vertebral section (i.e.: cervical, thoracic, lumbar) affected by the disease. Eight additional individuals (8/90 (8.89%)) were found to have two complete vertebral sections affected by spondylosis deformans.

Sled dogs were affected at multiple contiguous vertebrae at a rate of 5/12 (41.67%) (Table 5.6). The average number of contiguous affected vertebrae was 7 vertebrae. One individual (1/12 (8.33%)) was affected at every vertebra in an entire vertebral section.

Table 5.6: Multiple contiguous vertebrae affected with spondylosis deformans in dogs and wolves

	Non-transport Dogs	Sled Dogs	Wolves
	(n=90)	(n=12)	(n=51)
	n (%)	n (%)	n (%)
With ≥ 3 Contiguous Affected Vertebrae	64(71.11)	5(41.67)	17(33.33)
1 Affected Section	8(8.89)	1(8.33)	1(1.96)
2 Affected Sections	8(8.89)	0(0.00)	2(3.92)
Average # Contiguous Affected Vertebrae	8.89	7	9.47

Wolves were affected at multiple contiguous vertebrae in 17/51 (33.33%) individuals (Table 5.6). Of those affected 1 individual (1/51 (1/96%)) was affected with spondylosis deformans in every vertebrae of an entire vertebral section and 2 individuals (2/51 (3.92%)) had affected endplates in every vertebra of two entire vertebral sections. The average number of contiguous vertebrae affected was 9.47.

Distribution of osteophytes: The rates at which each group and spinal region were affected are presented in Table 5.7. For each analytic group of canids, data on the distribution of affected endplates by region is presented in Figures 5.2-5.4. Across the groups of canids analyzed here, non-transport dogs had a significantly higher proportion of endplates affected with spondylosis deformans (1468/7334 (20.02%)) when compared to the other groups (non-transport dogs versus sled dogs, X^2=7.87, p=0.0017; non-transport dogs versus wolves, X^2=1361.49, p=<0.0001). Sled dogs had a lower proportion of affected endplates (163/1026 (15.89%)) than non-transport dogs but were significantly more affected than wolves (sled dogs versus wolves, X^2=336.13, p=<0.0001). Wolves had the least number of affected endplates (449/12981 (3.46%)).

It should be noted, however, that when the wild wolves and captive wolves were separately assessed, captive wolves (180/700 (25.71%)) had a much higher proportion of affected vertebrae than their wild counterparts (269/12281 (2.19%)) or any other canid group. The differences between the captive and wild groups was highly significant (X^2=1059.51, p=<0.0001). Differences between the captive wolves and the non-transport dogs (X^2=10.11, p=0.0004) and between the captive wolves and sled dogs (X^2=20.22, p=<0.0001) were also significant.

Non-transport dogs were least affected in the cervical region of the spine with 213/1902 (11.20%) of all cervical endplates affected. These same dogs had 781/3532 (22.11%) thoracic endplates affected with peaks in frequency at the T1 cranial, T5 caudal, T6 caudal, and T9 caudal endplates (Figures 5.2 & 5.3). The lumbar region was the most affected region in this group with 474/2036 (23.28%) of endplates affected by osteophytes with peaks at the cranial L3 and caudal L7 endplates. While the rate at which cervical vertebrae were affected differed from the other regions significantly (cervical versus thoracic, X^2=80.49, p=>0.0001; cervical vs. lumbar, X^2=82.29, p=<0.0001) the difference between thoracic and lumbar vertebrae was small and could be due to chance (X^2=0.78, p=0.3148).

As with the non-transport dogs, the cervical vertebrae were least affected in sled dogs with a rate of 11/266 (4.14%) cervical endplates affected (Table 5.7). In these dogs the thoracic region was affected at a rate of 50/494 (10.12%) endplates with peaks at the T2 and T3 cranial endplates (Figure 5.3). Sled dogs were also most frequently affected by spondylosis deformans at the lumbar region with 44/266 (16.54%) of lumbar endplates affected. Peaks in frequency

Table 5.7: Distribution of endplates affected with spondylosis deformans by vertebral region in dogs and wolves and percentage of total region affected

	Non-transport dogs	Sled dogs	Wolves
	(n=7334)	(n=1026)	(n=12981)
	n (%)	n (%)	n (%)
Cervical	213/1902(11.20)	11/266(4.14)	49/3358(1.46)
Thoracic	781/3532(22.11)	50/494(10.12)	302/6251(4.83)
Lumbar	474/2036(23.28)	44/266(16.54)	98/3372(2.91)
Total	**1468/7334(20.02)**	**163/1026(15.89)**	**449/12981(3.46)**

occurred at the cranial and caudal L3 and L7 caudal endplates. In this group the rates at which all three regions were affected differed significantly (cervical versus thoracic, X^2=7.72, p=0.0038; cervical versus lumbar, X^2=19.8, p=<0.0001; thoracic versus lumbar, X^2=5.76, p=0.010).

Among wolves the cervical region was least affected with 49/3358 (1.46%) cervical endplates affected. In contrast with the dogs, wolves were more affected by spondylosis deformans in the thoracic region than other regions with 302/6251 (4.83%) thoracic endplates affected. Peaks occurred at the T1 cranial and T6 cranial endplates (Figure 5.2). The lumbar vertebral endplates were affected at a rate of 98/3372 (2.91%) with peaks at the L1 cranial and L7 caudal endplates. As with the sled dogs there were significant differences in the rates at which all three regions were affected (cervical versus thoracic, X^2=68.00, p=<0.0001; cervical versus lumbar, X^2=16.13, p=<0.0001; thoracic versus lumbar, X^2=19.53, p=<0.0001).

In non-transport dogs, sex based differences in the distribution of osteophytes were observed. Females had a higher frequency (134/796 (16.83%)) of affected endplates in the cervical region than males (66/686 (7.60%)). The differences between the two groups were highly significant (X^2=29.43, p=<0.0001). Males and females were similarly affected in the thoracic region but again differed in distribution of osteophytes in the lumbar region. Females were affected at a rate of 273/796 (34.30%) and the frequency in males was 175/866 (20.21%).

Figure 5.2: Distribution of osteophytes in dogs and wolves

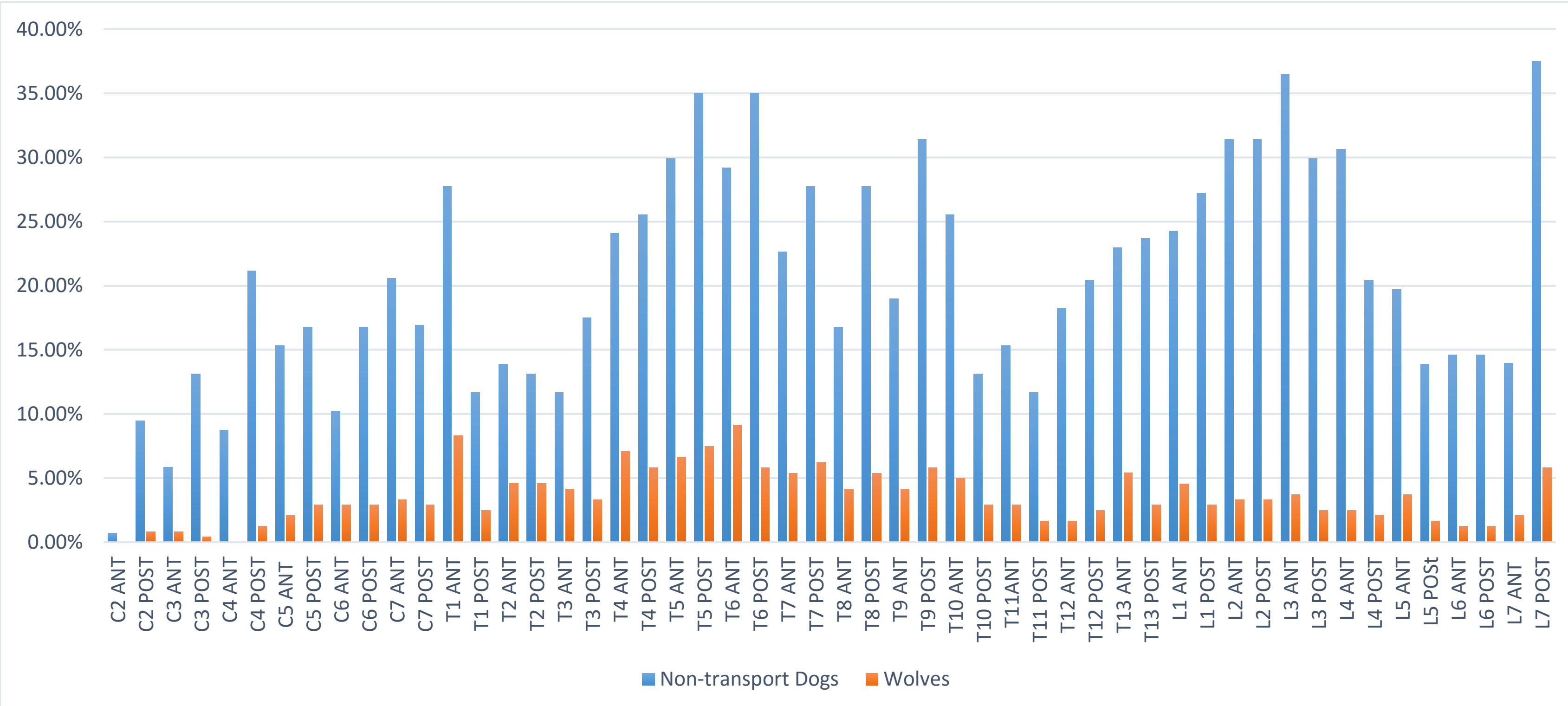


Figure 5.3: Distribution of osteophytes in dogs

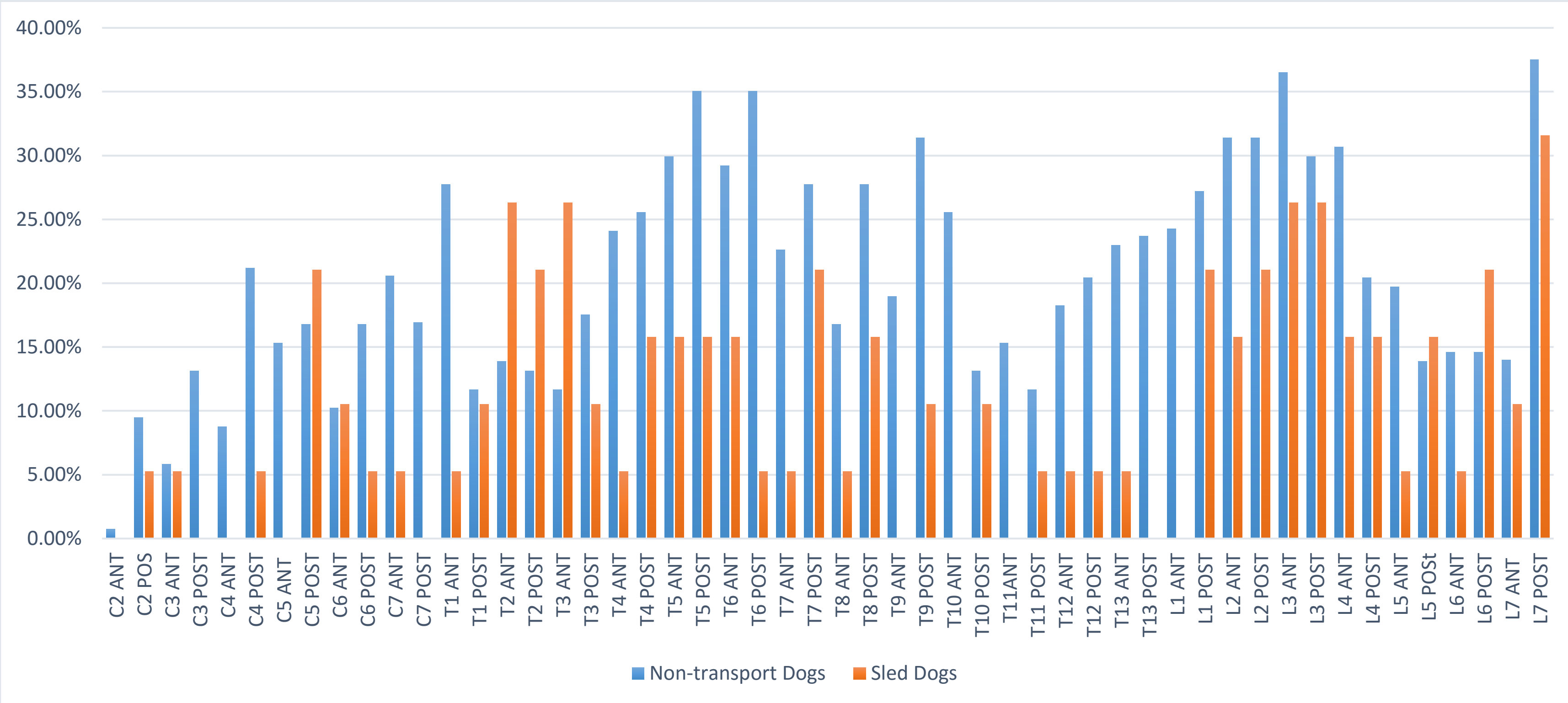


Figure 5.4: Distribution of osteophytes in non-transport dogs by sex

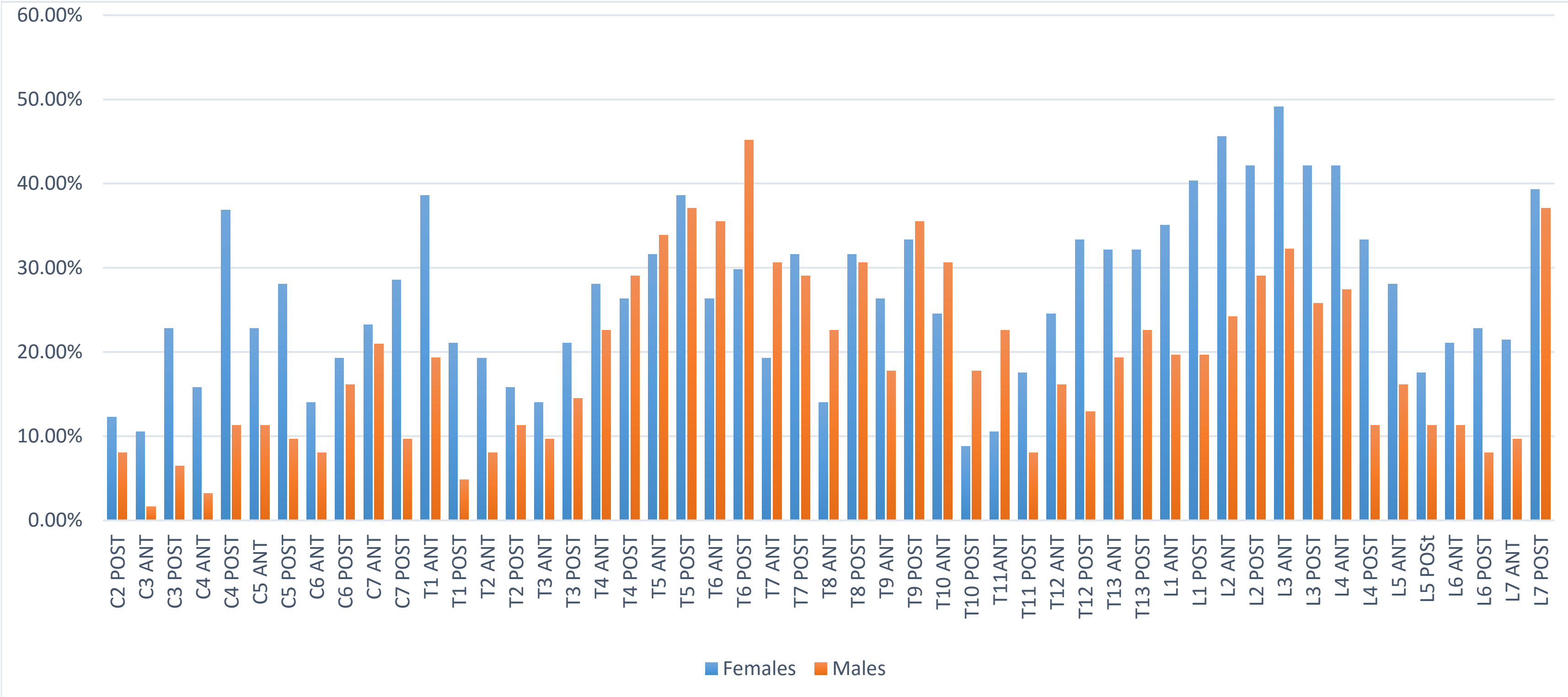


Table 5.8: Severity of spondylosis deformans in affected endplates of dogs and wolves

	Non-transport dogs	**Sled dogs**	**Wolves**
	n (%)	n (%)	n (%)
Grade 1	985(67.14)	86(52.76)	296(65.92)
Grade 2	450(30.67)	19(11.66)	137(30.51)
Grade 3	33(2.25)	0(0.00)	16(3.56)
Average Grade	1.35	1.21	1.38

The differences between the two groups were highly significant (X2=30.54, p=<0.0001). Visual comparison of the distribution of osteophytes in female and male non-transport dogs is illustrated in Figure 5.4. There were no significant differences observed in the distribution of osteophytes by sex in wolves, and the sled dog population was too small to provide meaningful results.

Stages of osteophytes: Spondylosis deformans was evaluated at each affected endplate using a scoring system to denote the severity of the disease at each location. This data is presented in Table 5.8 and Figures 5.5-5.7 below. In all groups, grade 1 osteophytes were most common, and grade 3 osteophytes were least common. Non-transport dogs had 1468/7334 (20.02%) total affected endplates. Of those affected endplates, 985 (67.14%) were grade 1 osteophytes, 450 (30.67%) were grade 2 osteophytes, and 33 (2.25%) were grade 3 osteophytes. The average grade of affected endplates for non-transport dogs was 1.35. In general, severe osteophytes were more likely to occur in lower thoracic and lumbar vertebrae. The distribution of osteophyte grades in non-transport dogs is illustrated in Figure 5.5 below.

Sled dogs were affected with spondylosis deformans in 163/1023 (15.89%) assessed endplates. Of these affected endplates, 86 (52.76%) had grade 1 osteophytes and 19 (11.66%) had grade 2 osteophytes (Table 5.8). None of the sled dogs in the sample were affected with grade 3 osteophytes. The average grade of affected endplate was 1.21 in this group. The distribution of osteophytes by vertebrae is illustrated in Figure 5.6 below.

Figure 5.5: Severity of spondylosis deformans in non-transport dogs

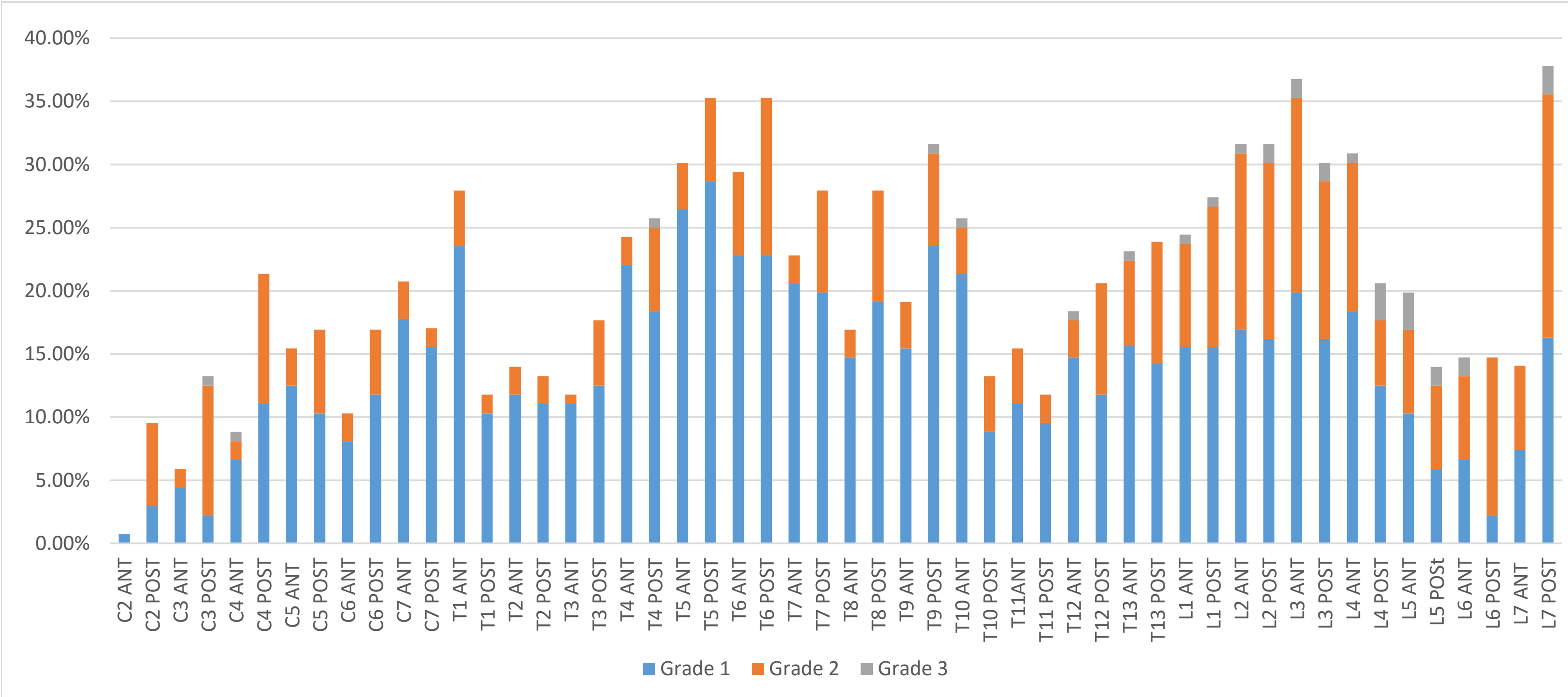


Figure 5.6: Severity of spondylosis deformans in sled dogs

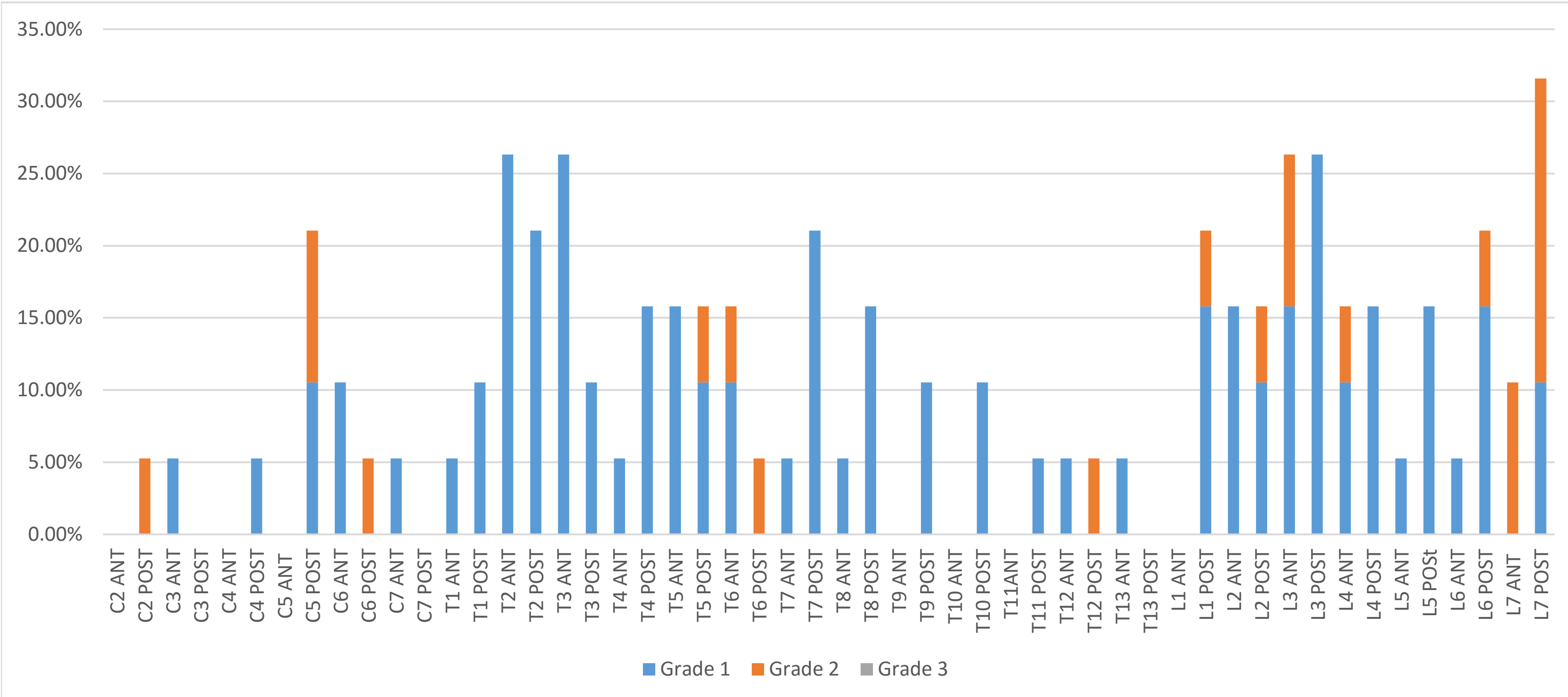


Figure 5.7: Severity of spondylosis deformans in wolves

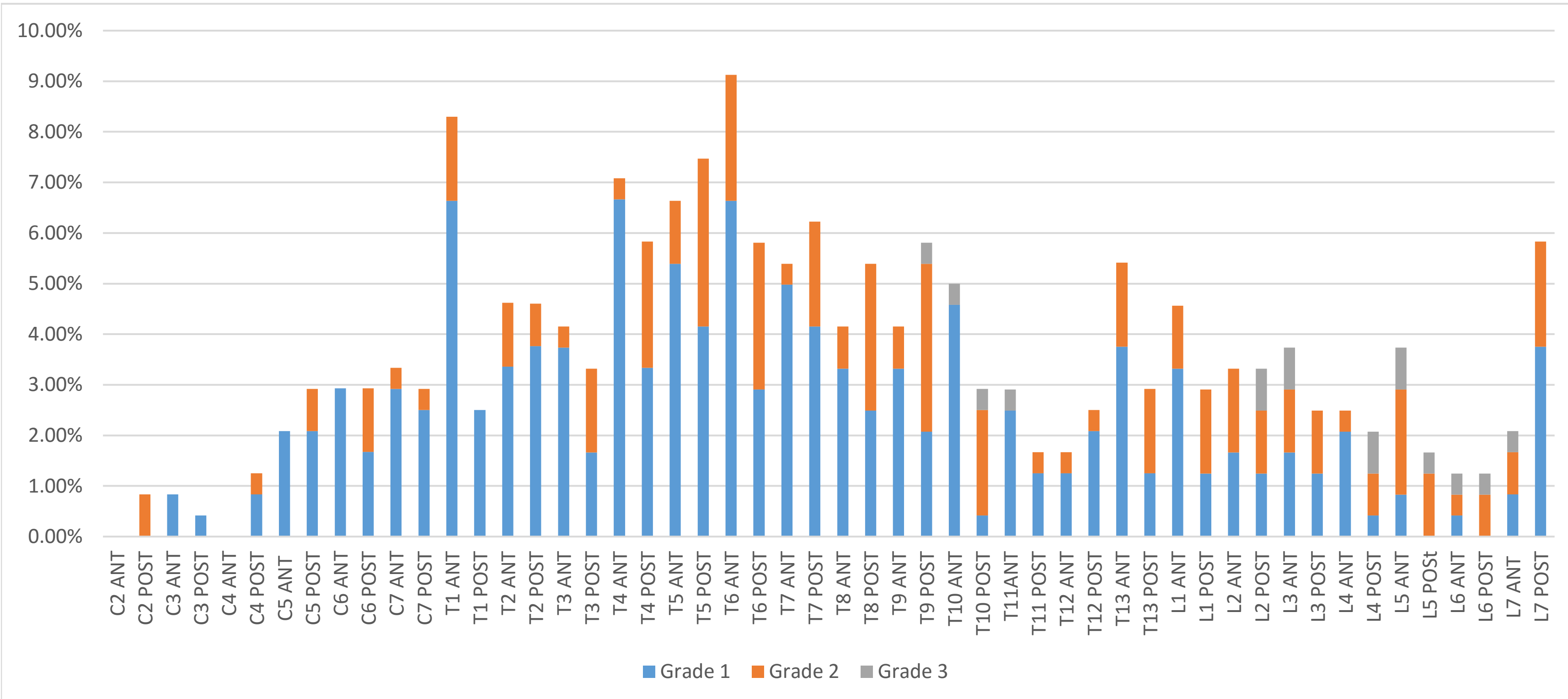


Table 5.9: Frequency of osteophyte grades in non-transport dog age groups by a) percentage of assessed endplates affected, b) relative frequency of affected endplates by grade

5.9a.				
Age Group	**Assessed Endplates**	**Grade 1**	**Grade 2**	**Grade 3**
0-2	270	7(2.59)	5(1.85)	0(0.00)
3-5	432	20(4.63)	3(0.69)	1(0.23)
6-8	486	48(9.88)	8(1.65)	2(0.41)
9-11	1294	288(22.26)	157(12.13)	22(1.70)
12-14	1024	225(21.97)	117(11.43)	0(0.00)
15-17	644	155(24.07)	70(10.87)	5(0.78)
Total	**4150**	**743(17.90)**	**360(8.67)**	**30(0.72)**

5.9b.				
Age Group	**Affected Endplates**	**Grade 1**	**Grade 2**	**Grade 3**
0-2	12	7(58.33)	5(41.67)	0(0.00)
3-5	24	20(83.33)	3(12.5)	1(4.17)
6-8	58	48(82.76)	8(13.79)	2(3.45)
9-11	467	288(61.67)	157(33.62)	22(4.71)
12-14	342	225(65.79)	117(34.21)	0(0.00)
15-17	230	155(67.39)	70(30.43)	5(2.17)
Total	**1133**	**743(65.58)**	**360(31.77)**	**30(2.65)**

Wolves were affected with spondylosis deformans in 449/12981 (3.46%) total endplates. Of these affected endplates 49/3358 (1.46%) were affected with grade 1 osteophytes, 302/625 (4.83%) were affected with grade 2 osteophytes, and 98/3372 (2.91%) were affected with grade 3 osteophytes. For the group as a whole the average grade of affected endplate was 1.38. The occurrence of grade 3 osteophytes was limited to the lower thoracic and lumbar vertebral regions. The distribution of osteophytes by vertebrae in wolves is illustrated above in Figure 5.7.

In general, the occurrence of all grades of osteophytes increased with age across all groups. In non-transport dogs there was a substantial increase in the occurrence of grade 1 and

Figure 5.8: Distribution of osteophyte grades in all assessed endplates for non-transport dog age groups

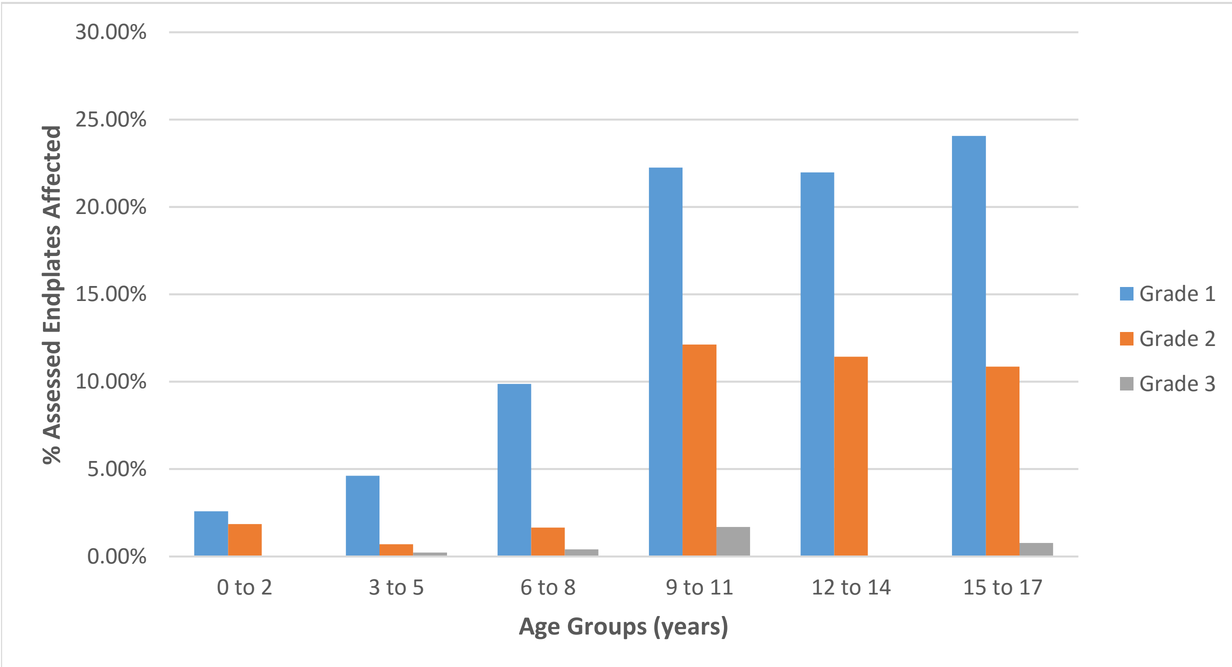


Figure 5.9: Distribution of osteophyte grades in all affected endplates for non-transport dog age groups

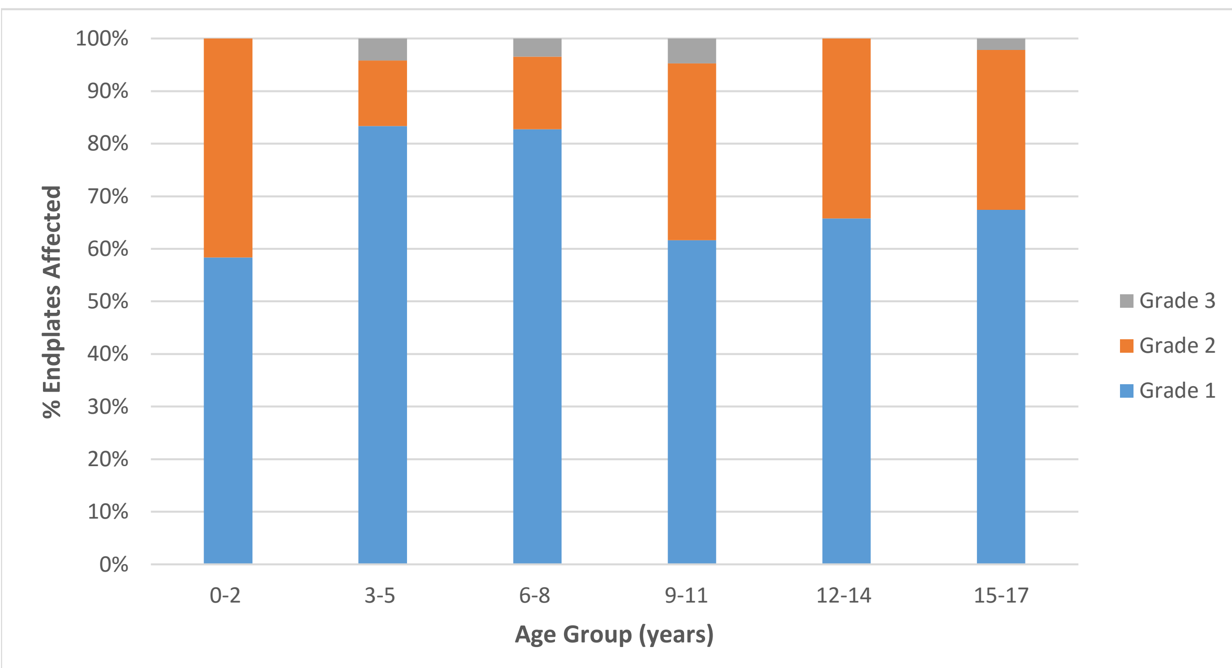


Table 5.10: Frequency of osteophyte grades in sled dog age groups by a) percentage of assessed endplates affected, b) relative frequency of affected endplates by grade

5.10a.

Age Group	Assessed Endplates	Grade 1	Grade 2	Grade 3
3-5	108	4(3.70)	0(0.0)	0(0.00)
9-11	324	21(6.48)	7(2.16)	0(0.00)
12-14	108	42(38.89)	5(4.63)	0(0.00)
Total	540	67(12.41)	12(22.22)	0(0.00)

5.10b.

Age Group	Affected Endplates	Grade 1	Grade 2	Grade 3
3-5	48	4(100.00)	0(0.0)	0(0.00)
9-11	28	21(75.00)	7(25.00)	0(0.00)
12-14	47	42(89.36)	5(10.64)	0(0.00)
Total	79	67(84.81)	12(15.19)	0(0.00)

grade 2 osteophytes after 8 years of age (Table 5.9) though stage 3 osteophytes were relatively rare in all groups and did not seem to be linked to age. These patterns are illustrated in Figures 5.8 & 5.9.

The total number of sled dogs assessed by age was very small but the individuals analyzed followed a pattern similar to the non-transport dogs. The overall number of osteophytes increased markedly after 11 years of age but increased age was not necessarily related to relative increases in the severity of the osteophytes (see Tables 5.10 & and Figures 5.10 and 5.11).

In wolves there was a steady increase in the total number of osteophytes as age increased and a marked increase in the occurrence of osteophytes after 8 years of age (Table 5.11 and Figures 5.12 & 5.13). As with the dogs, grade 1 osteophytes were consistently the most numerous and again, increased age did not appear to be a predictor of more severe osteophytes.

Figure 5.10: Distribution of osteophyte grades in all assessed endplates for sled dog age groups

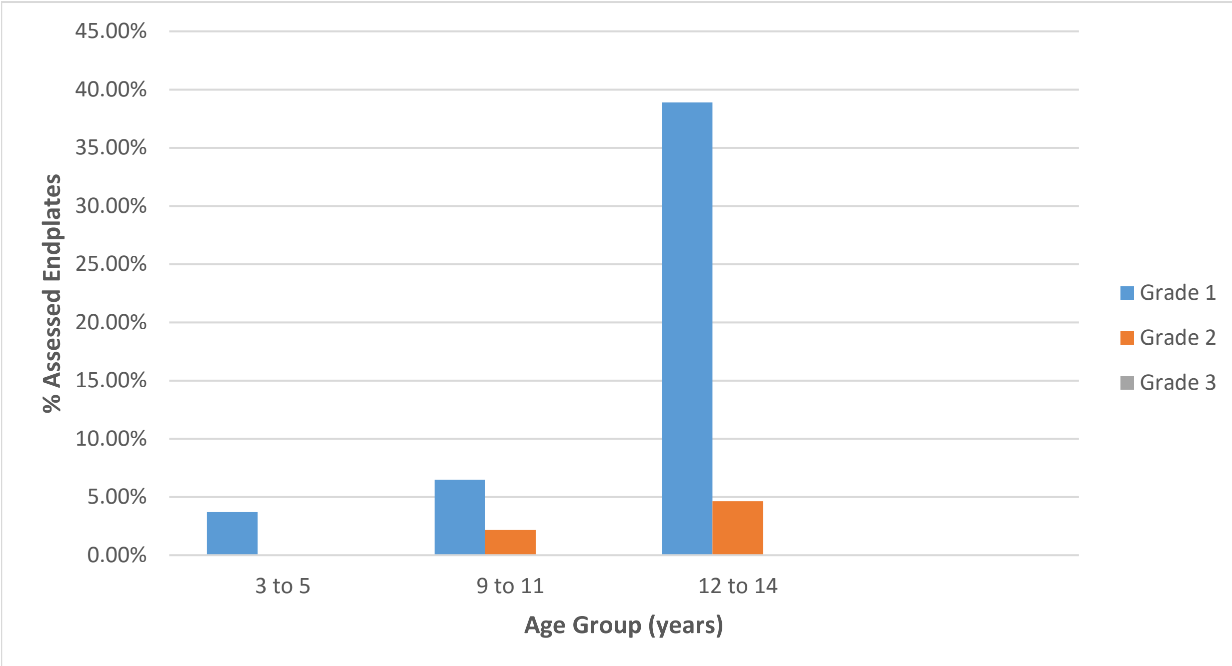


Figure 5.11: Distribution of osteophyte grades in all affected endplates for sled dog age groups

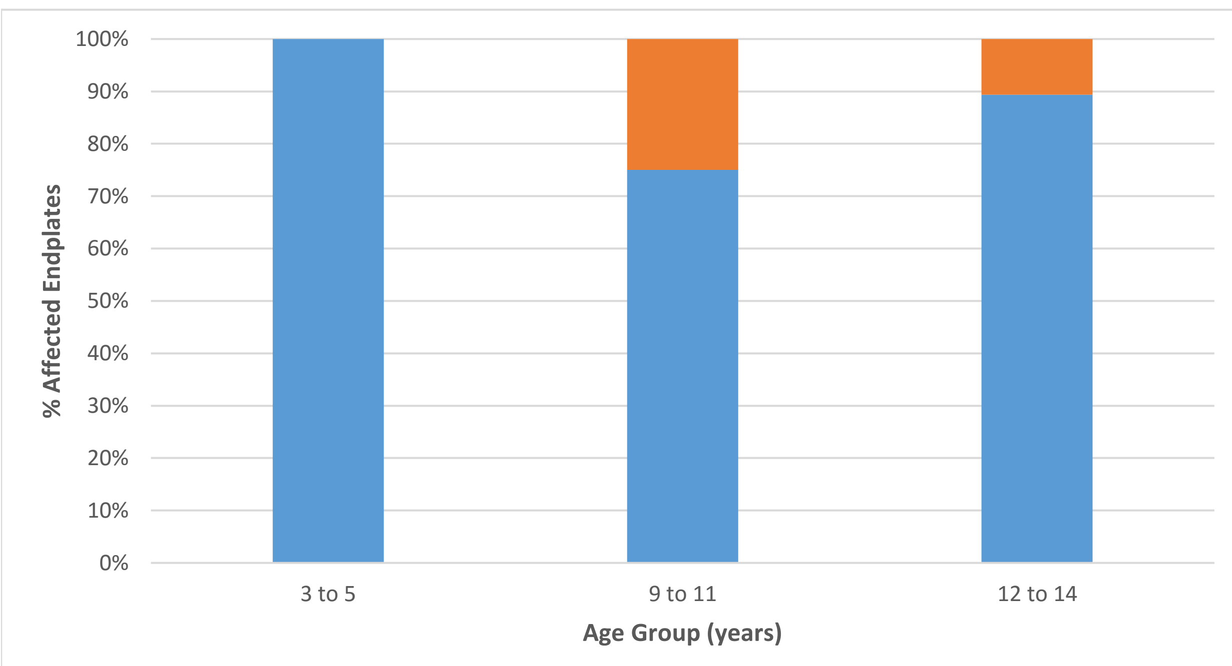


Table 5.11: Frequency of osteophyte grades in wolf age groups by a) percentage of assessed endplates affected, b) relative frequency of affected endplates by grade

5.11a.

Age Group	Assessed Endplates	Grade 1	Grade 2	Grade 3
0-2	2592	10(0.39)	6(0.23)	2(0.08)
3-5	702	9(1.28)	4(0.57)	(0.00)
6-8	322	31(9.63)	10(3.11)	(0.00)
9-11	160	38(23.75)	30(18.75)	2(1.25)
12-14	54	16(29.63)	21(38.89)	8(14.81)
Total	3830	104(2.72)	71(1.85)	12(0.31)

5.11b.

Age Group	Affected Endplates	Grade 1	Grade 2	Grade 3
0-2	18	10(55.56)	6(33.33)	2(11.11)
3-5	13	9(69.23)	4(30.77)	0(0.00)
6-8	41	31(69.23)	4(30.77)	0(0.00)
9-11	70	38(54.29)	30(42.86)	2(2.86)
12-14	45	16(35.56)	21(46.67)	8(17.78)
Total	187	104(55.61)	71(37.97)	12(6.42)

Figure 5.12: Distribution of osteophyte grades in all assessed endplates for wolf age groups

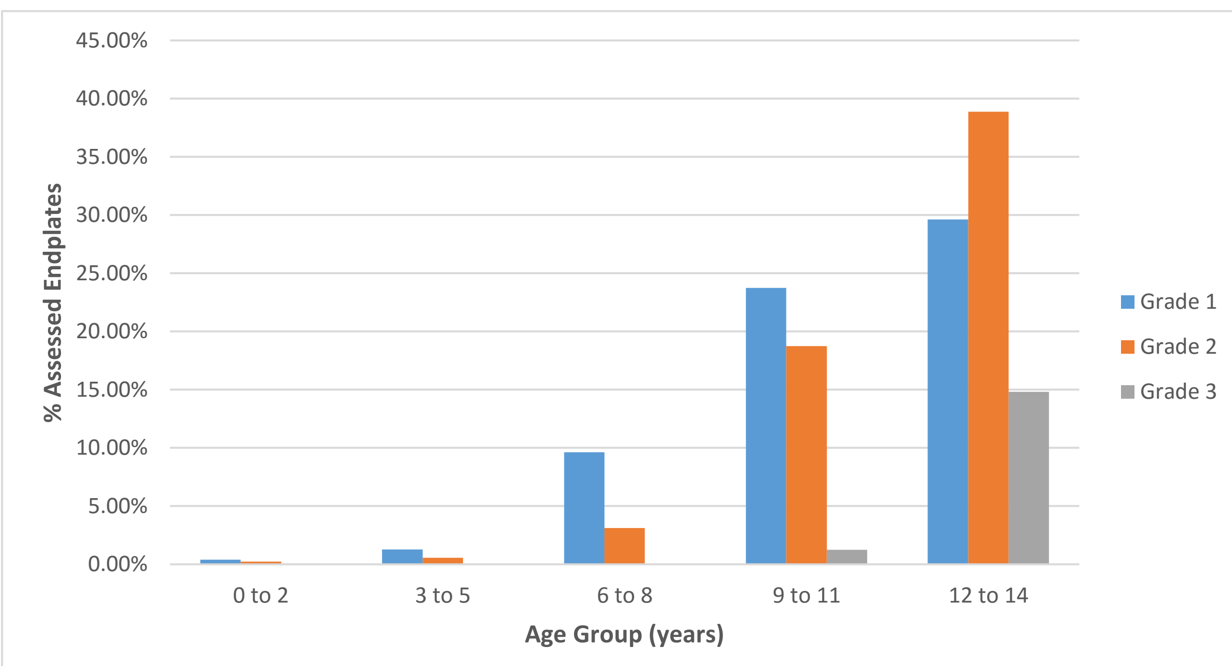
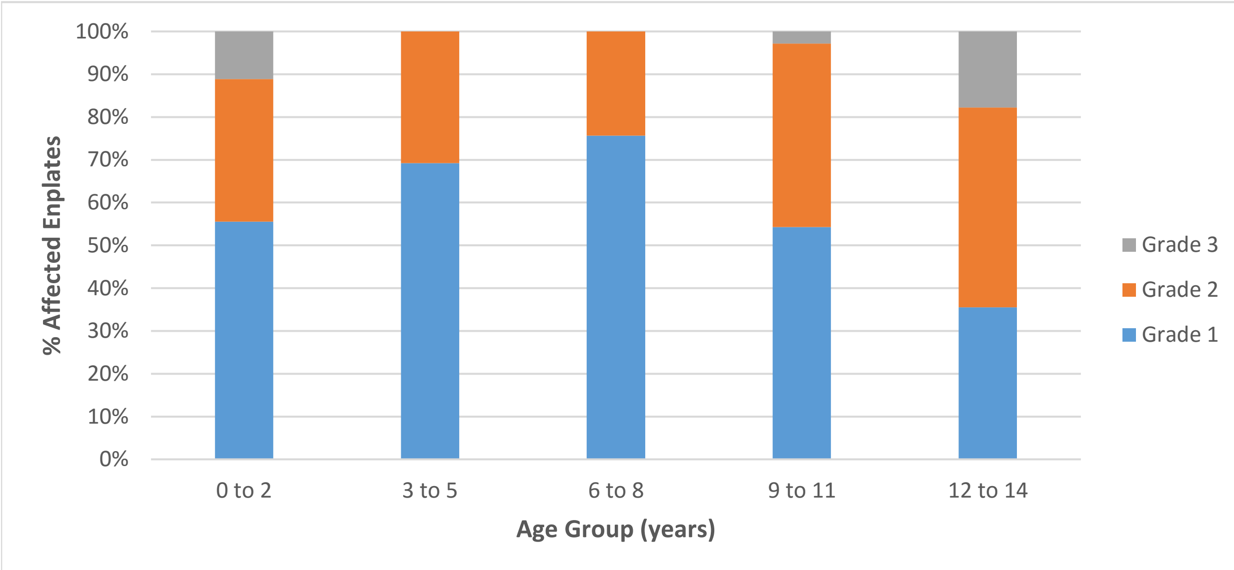


Figure 5.13: Distribution of osteophyte grades in all affected endplates for wolf age groups



Spinous Process Deformations

Incidence and distribution: Individuals were assessed for deformations of the spinous processes in the form of fractures and bending which exceeded ten degrees to the left or right. Overall, deformations of both types were more common among wolves than among dogs regardless of their use in transport activities. The frequencies at which each group was affected are presented in Tables 5.12 & 5.13 below.

Non-transport dogs were the only dog group affected by bent spinous processes with a frequency of 6/117 (5.13%) individuals affected (Table 5.12). No dinogoes were affected by bent processes but it is important to note that the sample size for this group was very small. When dingoes are removed from the non-transport dog group the frequency of affected dogs is 6/113 (5.31%). Among affected dogs, the average number of affected processes per dog was 1.67.

Table 5.12: Frequency of bent spinous processes with percentage of individuals affected for a) dogs and b) wolves

5.12a.

	Non-Transport Dogs					Transport Dogs
	All	**Dogs**	**Dingoes**	**Captive Dingoes**	**Wild Dingoes**	**Sled Dogs**
	(n=117)	(n=113)	(n=4)	(n=2)	(n=2)	(n=19)
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Female	2/53(3.77)	2/53(3.77)	0/0(0.00)	0/0(0.00)	0/0(0.00)	0/4(0.00)
Male	4/50(8.00)	4/47(8.51)	0/3(0.00)	0/2(0.00)	0/1(0.00)	0/7(0.00)
Unknown	0/14(0.00)	0/13(0.00)	0/1(0.00)	0/0(0.00)	0/1(0.00)	0/8(0.00)
Adult	6/114(5.26)	6/110(5.45)	0/4(0.00)	0/2(0.00)	0/2(0.00)	0/19(0.00)
Juvenile	0/3(0.00)	0/3(0.00)	0/0(0.00)	0/0(0.00)	0/0(0.00)	0/0(0.00)
Total	**6(5.13)**	**6(5.31)**	**0(0.00)**	**0(0.00)**	**0(0.00)**	**0(0.00)**

5.12b.

	All	**Wild**	**Captive**	**Inbred**	**Non-inbred**
	(n=190)	(n=178)	(n=12)	(n=80)	(n=110)
	n (%)	n (%)	n (%)	n (%)	n (%)
Female	9/83(10.84)	9/79(11.39)	0/4(0.00)	4/35(11.43)	5/45(10.42)
Male	11/95(11.58)	11/89(12.36)	0/6(0.00)	7/43(16.28)	4/52(7.69)
Unknown	1/12(8.33)	1/10(10.00)	0/2(0.00)	1/2(50.00)	0/10(0.00)
Adult	19/132(14.39)	19/121(15.70)	0/12(0.00)	10/60(16.67)	9/72(12.50)
Juvenile	2/58(3.45)	2/57(3.51)	0/1(0.00)	2/20(10.00)	0/38(0.00)
Total	**21(11.05)**	**21(11.80)**	**0(0.00)**	**12(15.00)**	**9(8.18)**

The frequency of bent spinous processes in wolves was 21/190 (11.05%). This rate differed from the non-transport dog group at a near significant level (X^2=2.89, p=0.0759) suggesting real differences exist between the two groups. Within the wolf group only wild wolves were affected. Removing captive wolves from the group changed the frequency to 21/178 (11.80%). Inbred wolves were affected at a higher rate than the non-inbred group, but the difference was not significant (X^2=1.95, p=0.1389). Inbred wolves had a frequency of 12/80 (15.00%) processes affected whereas the non-inbred wolves were affected at a frequency of 9/110 (8.18%). Among those wolves affected by bent spinous processes, the average number of affected processes was 1.81.

Non-transport dogs were affected by low rates of spinous process fractures with a frequency of 1/117 (0.85%) of individuals affected (Table 5.13). No dingoes were affected by fractured spinous processes and when this group is removed the frequency is 1/113 (0.88%). The rate of fractured spinous processes was slightly higher in sled dogs, which were affected at a rate of 1/19 (5.26%). In affected dogs the average number of fractured processes per individual was 1.00.

Wolves were affected by fractured spinous processes at a rate of 26/190 (13.68%) (Table 5.13**)**. This rate differed significantly from the non-transport dogs (p=<0.0001) but not from the sled-dogs (p=0.479) though this may not be statistically meaningful due to the extreme differences in the sample sizes being compared. Only wild wolves were affected by fractured spinous processes. When the captive individuals are removed from the group the frequency is 26/178 (14.61%). While the differences between the wild and captive group are not statistically significant (p=0.1545), it is unclear if this is a meaningful comparison given the comparatively small sample size of the captive group. As with bent spinous processes, the inbred group was also affected by fractured spinous processes at a higher rate than the non-inbred group. Inbred wolves were affected at a rate of 15/80 (18.75%) whereas non-inbred individuals were affected at a rate of 11/110 (10.00%). The difference between the two groups was found to be near significant (p=0.0832). Affected wolves had an average of 1.76 vertebrae affected by a spinous process fracture.

There were no individual dogs affected by both bent spinous processes and fractured spinous processes. Among wolves 6/47 (12.77%) inidividuals were affected with both bent and fractured processes in their spinal column.

Table 5.13: Frequency of fractured spinous processes with percentage of individuals affected for a) dogs and b) wolves

5.13a.

	Non-Transport Dogs					Transport Dogs
	All	**Dogs**	**Dingoes**	**Captive Dingoes**	**Wild Dingoes**	**Sled Dogs**
	(n=117)	(n=113)	(n=4)	(n=2)	(n=2)	(n=19)
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Female	0/53(0.00)	0/53(0.00)	0/0(0.00)	0/0(0.00)	0/0(0.00)	0/4(0.00)
Male	0/50(0.00)	0/47(0.00)	0/3(0.00)	0/2(0.00)	0/1(0.00)	0/7(0.00)
Unknown	1/14(7.14)	1/13(7.69)	0/1(0.00)	0/0(0.00)	0/1(0.00)	1/8(12.50)
Adult	1/114(0.88)	1/110(0.91)	0/4(0.00)	0/2(0.00)	0/2(0.00)	1/19(5.26)
Juvenile	0/5(0.00)	0/3(0.00)	0/0(0.00)	0/0(0.00)	0/0(0.00)	0/0(0.00)
Total	**1(0.85)**	**1(0.88)**	**0(0.00)**	**0(0.00)**	**0(0.00)**	**1(5.26)**

5.13b.

	All	**Wild**	**Captive**	**Inbred**	**Non-inbred**
	(n=190)	(n=178)	(n=12)	(n=80)	(n=110)
n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Female	9/83(10.84)	12/79(15.19)	0/4(0.00)	6/35(11.43)	6/48(12.50)
Male	11/95(11.58)	14/89(15.73)	0/6(0.00)	9/43(20.93)	5/52(9.62)
Unknown	1/12(8.33)	0/10(0.00)	0/2(0.00)	0/2(0.00)	0/10(0.00)
Adult	24/132(18.18)	24/121(19.83)	0/11(0.00)	13/60(21.67)	11/72(15.28)
Juvenile	2/58(3.45)	2/57(3.51)	0/1(0.00)	2/20(10.00)	0/38(0.00)
Total	**26/190(13.68)**	**26(14.61)**	**0(0.00)**	**15(18.75)**	**11(10.00)**

Sex: Among dogs males were affected by bent spinous processes at a higher rate than females (Table 5.12). Specifically, males were affected at a rate of 4/50 (8.00%) compared to 2/53 (3.77%) in females. There was no difference in frequency by sex for fractured spinous processes in dogs (Table 5.13). Among wolves, males were also affected by bent sprinous processes at a higher rate than females. Males were affected at a rate of 11/95 (11.58%) compared to a frequency of 9/83 (10.84%) in females. Males were also more affected among inbred wolves with a frequency of 7/43 (16.28%) compared to females at a rate of 4/35

(11.43%). However, males were less affected than females in non-inbred wolves, with males affected at a rate of 4/52 (7.69%) compared to females at 5/45 (10.42%).

Age: In dogs, only adult individuals were affected with bent or fractured spinous processes (Tables 5.12 & 5.13). Adults were affected with bent processes at a rate of 6/114 (5.26%) and fractured spinous processes at a rate of 1/117 (0.85%). There were not enough individuals of known age with spinous process deformations to observe trends across age groups.

Among wolves, adults were affected with bent spinous processes at a rate of 19/132 (14.39%) whereas juveniles were less affected at a rate of 2/58 (3.45%). Adults were affected with fractured spinous processes at a rate of 24/132 (18.18%) and juveniles were affected at a rate of 2/58 (3.45%). When individuals of known age were assessed for the occurrence of spinous process deformations, there was a tendency for the number of both bent and fractured processes to increase with age. This trend is illustrated in Figure 5.14.

This pattern in wolves was repeated in individuals with fractured spinous processes (Table 5.13). Overall males were affected at a higher rate of 11/95 (11.58%) compared to females at 9/83 (10.84%). Inbred male wolves were affected at a frequency of 9/43 (20.93%) whereas females were affected at a rate of 6/35 (11.43%). Among non-inbred wolves males were affected at a rate of 5/52 (9.62%) compared to females at 6/48 (12.50%).

While males and females commonly differed in the frequency at which they were affected with deformities of the spinous processes, no significant differences were observed. In other words, there was no clear sex-based pattern of spinous process deformities in either dogs or wolves.

Figure 5.14: Percentage of wolves affected by spinous process deformations by age group

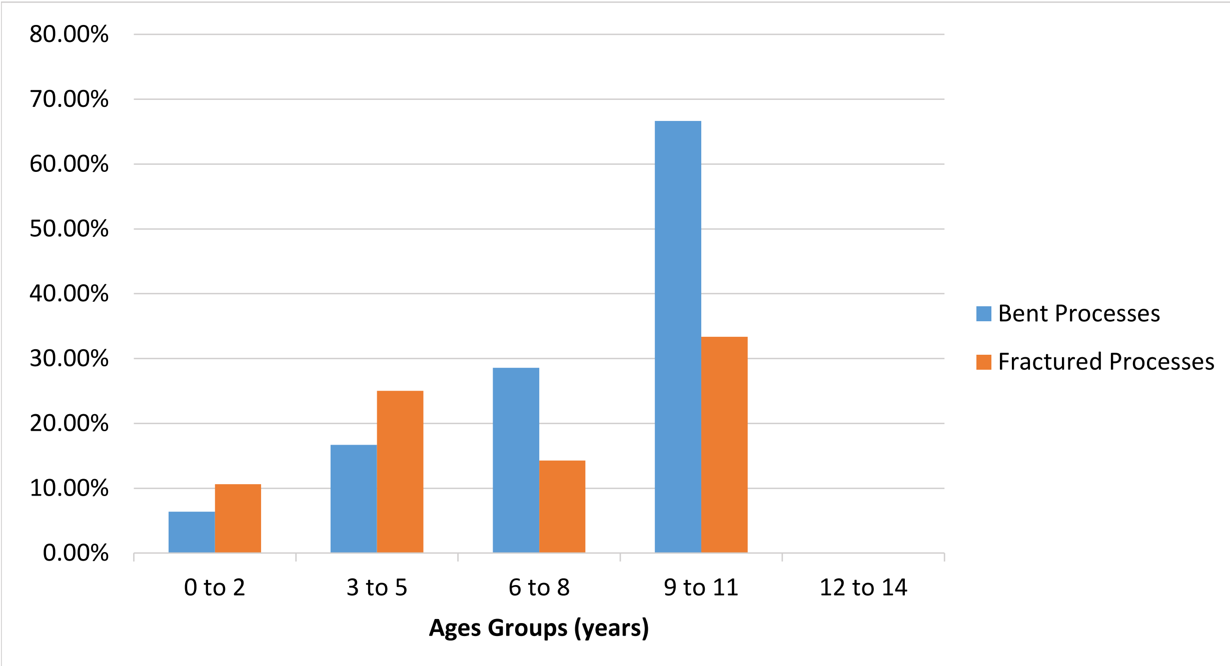


Figure 5.15: Distribution of bent and fractured spinous process deformations in non-transport dogs

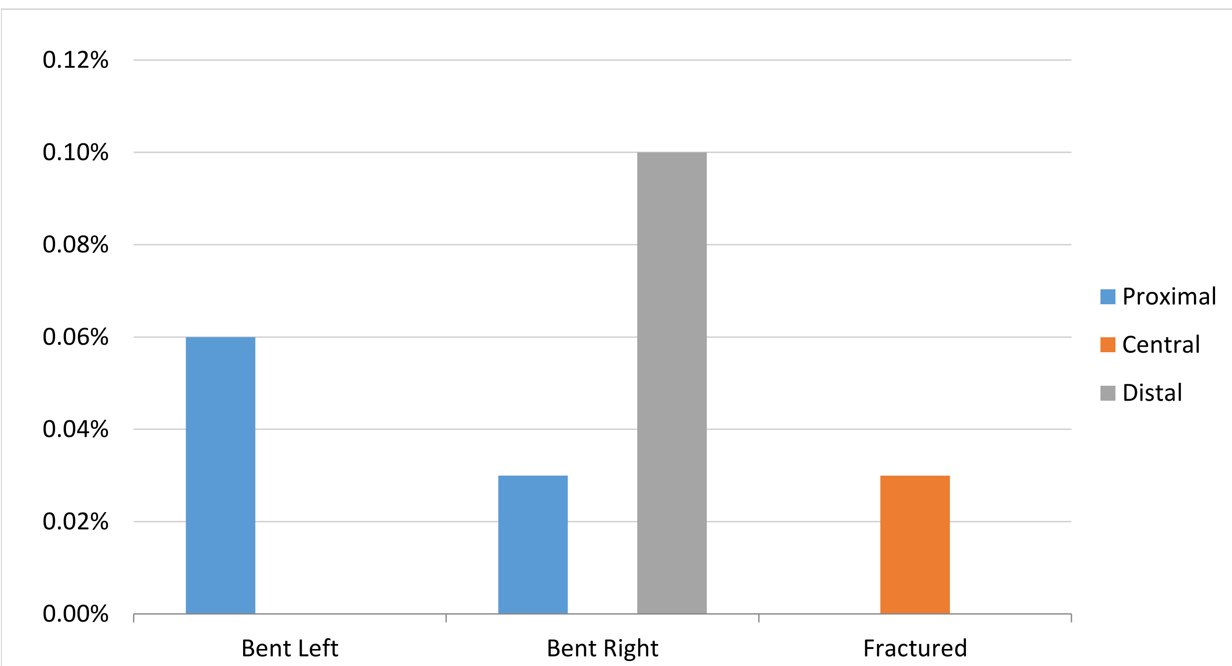
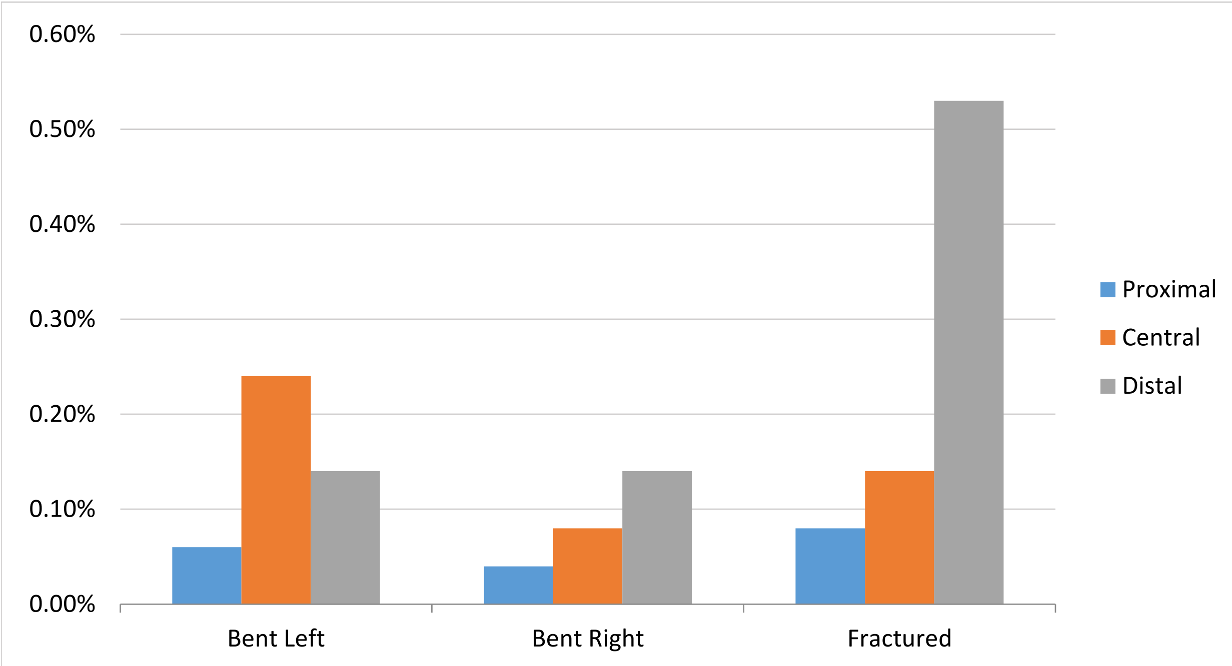


Figure 5.16: Distribution of bent and fractured spinous process deformations in wolves



Distribution of spinous process deformations: The location and distribution of bends and fractures to the spinous process was assessed for all affected individuals. Frequencies are presented based upon the percentage of assessed vertebrae affected and results are illustrated in figures 5.15-5.16. For the non-transport dog group a total of 3144 vertebrae were assessed (Figure 5.15**)**. Of these vertebrae 6/3144 (0.19%) had bent spinous processes. Among the affected vertebrae 2/3144 (0.06%) were bent to the left at the proximal portion and 4/3144 (0.13%) were bent to the right with 1/3144 (0.03%) bent proximally and 3/3144 (0.10%) bent distally. There was only one incidence of fractured processes in the non-transport group. The fracture occurred centrally for a frequency of 1/3144 (0.03%) fractured processes total.

Sled dog specimens analyzed here showed no cases of bent spinous processes. Out of the 513 vertebrae assessed, only 3/513 (0.58%) showed fractures. These fractures occurred proximally (1/513 (0.19%)), centrally (1/513 (0.19%)), and distally (1/513 (0.19%)).

Wolves experienced the highest overall rate of deformations. A total of 5101 vertebrae were assessed for this group (Figure 5.16). The occurence rate of bent spinous processes was 35/5101 (0.69%). Of these 22/5101 (0.43%) were bent to the left, with 3/5101 (0.06%) bent proximally, 12/5101 (0.24%) bent centrally, and 7/5101 (0.14%) bent distally. A total of 13/5101(0.25%) were bent to the right with 2/5101 (0.04%) bent proximally, 4/5101 (0.08%) bent centrally, and 7/5101 (0.14%) bent distally. A total of 38/5101 (0.74%) of spinous processes had suffered fractures with 4/5101 (0.08%) occuing proximally, 7/38 (0.14%) occuring centrally, and 27 (0.53%) occuring distally.

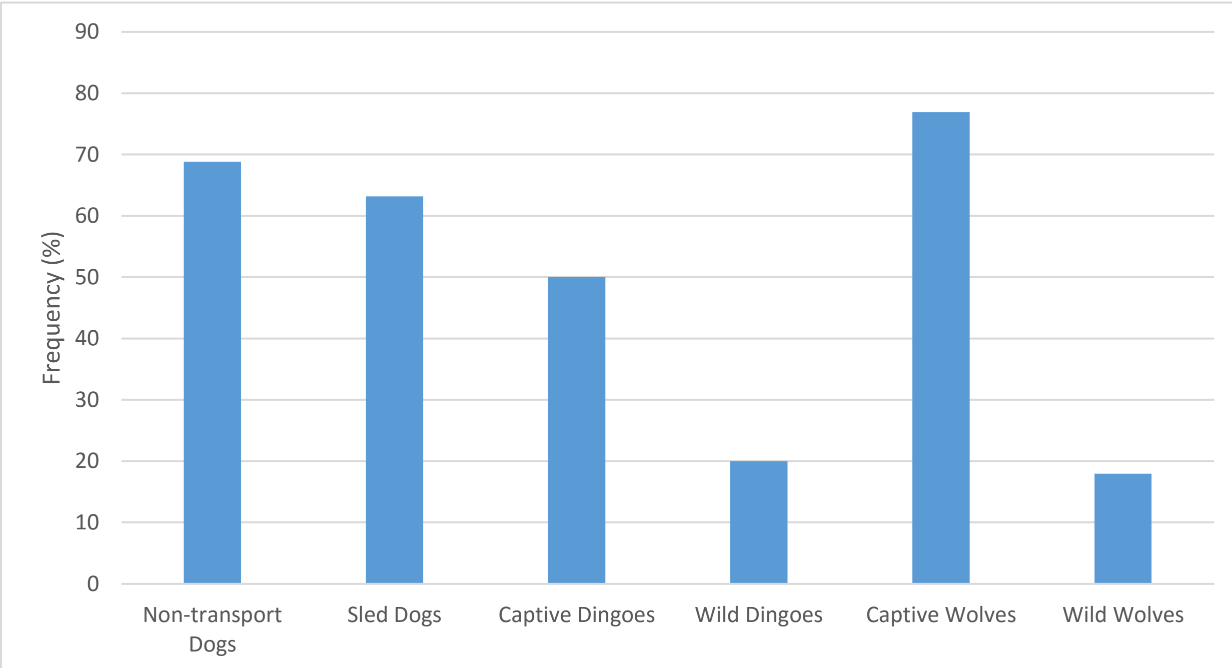
Chapter 6 : Discussion

Spondylosis deformans: Dogs were affected by spondylosis deformans at high rates with non-transport dogs suffering from the disease more frequently than sled dogs or wolves (Figure 6.1). Non-transport dogs were affected at a rate of 86/125 (68.80%). Sled dogs were slightly less affected-- the pathology was found in 12/19 (63.16%) individuals, but this difference was not statistically significant (X^2=0.08, p=0.6231).

In general wolves were considerably less affected by spondylosis deformans than either of the dog groups. Overall, 51/241 (21.16%) wolves were affected with the disease, but wolves living in captivity were affected at higher rates than any other canid group in the study with 10/13 (76.92%) of individuals having the lesions. This rate differs drastically from the frequency observed in wild wolves (41/228 (19.98%)) and is highly significant (p=<0.0001). Captive wolves were affected at a rate similar to dogs, suggesting that the environment in which a canid lives may contribute to its likelihood of developing the disease. Though the sample size was very small, dingoes also demonstrated this pattern, with 3/6 (50.00%) of captive dingoes affected with spondylosis as compared to 1/5 (20.00%) of the wild population.

Rates for both non-transport dogs and sled dogs were similar to the findings of other studies that looked at the occurrence of spondylosis deformans in dogs. For example, Morgan (1967a:52) found that 71 out of 116 (61%) individuals from various breeds were affected by the disease. In a similar study of 140 dogs from England, Read and Smith (1968:161) found that 75% were affected. In a separate study of dogs from England, the United States and Sweden, Morgan et al. (1967:59) found that 110 of 175 (62.8%) dogs were affected.

Figure 6.1: Frequency of spondylosis deformans in canids



Distribution of osteophytes in dogs was also similar to that seen in previous studies, though a few key differences were observed. Like Morgan (1967), Morgan et al. (1967), and Read and Smith (1968:164), the most commonly affected vertebrae were in the mid-thoracic and first few lumbar vertebrae as well as at the L7/sacral joint. However, the degree of cervical involvement in non-transport dogs was higher than in previous studies, and in sled dogs the first three thoracic vertebrae were much more affected than in other studies.

The rates observed among both non-transport and sled dogs in this study were also similar to the rates observed among the British Antarctic Survey's 1960s sled dogs. Bellars and Godsal (1969:33) reported that these sleds dogs were affected at a rate of 9/11 (81.82%) individuals. While the frequency observed in these sled dogs was higher than those observed among the non-transport or sled dogs assessed in the present study, the differences are not significant (versus this study's non-transport dogs, X^2=0.35, p=0.2825; versus this study's sled-dogs, X^2=0.35, p=0.2825) and may be the product of a comparatively small sample consisting exclusively of older dogs. As previously mentioned, the authors of the study clearly stated that the group of sled dogs observed were predisposed to spondylosis deformans because of their ages (Bellars and Godsal 1969:33-34).

Differences were observed, however, when the data from the present study was compared to the rates and distribution of osteophytes observed in archaeological dogs from Illinois and the Southeastern United States in Warren's 2004 study. Warren observed minor peaks in the frequency of spondylosis deformans in the first few thoracic vertebrae and in the lower thoracic and lumbar regions (Warren 2004:148-153). Frequencies near or exceeding 70% were observed from the twelfth thoracic through fifth lumbar vertebrae, which were much higher than that observed in any group in the present study.

In the present study, sled dogs, like Warren's sample, experienced a greater degree of involvement in the first few thoracic vertebrae than the non-transport group, but in general, modern canids were more affected in the mid-thoracic vertebrae than Warren's dogs and less affected in the lower thoracic and lumbar vertebrae. This is especially true of the wolves, which were most affected in the mid-thoracic vertebrae and presented a generally different pattern of distribution than the dogs in Warren's study.

It is not clear if the differences in the distribution of osteophytes between the dogs described by Warren and the canids in the present study occurred because the former dogs were used for carrying packs, as Warren has suggested (Warren 2004:153). In the present study, different patterns of osteophyte distribution were observed in male and female non-transport dogs. Though this does not necessarily explain the pattern of low mid-thoracic involvement in Warren's dogs, these sex based differences indicate that numerous variables can affect osteophyte distribution in dogs. While it remains possible that differences in mechanical forces influence the distribution of osteophytes in individuals, in the absence of data on spondylosis deformans in known pack dogs, other factors such as sex, breed, age, and size differences that are known to predispose dogs to marginal osteophytes should also be considered.

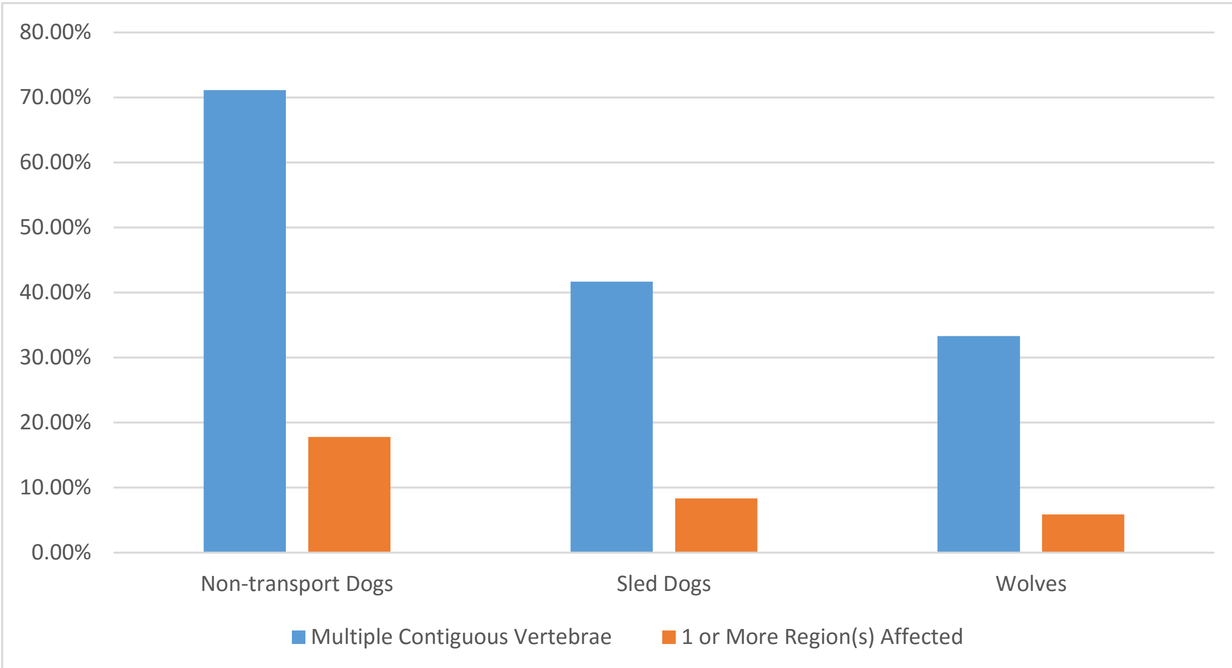
Overall, comparison with previous research on both sled dogs and non-transport dogs suggest that the frequencies of spondylosis deformans observed in this study are typical of dogs in general, regardless of their use in transport activities. Furthermore, the high rates at which dogs were affected by spondylosis deformans in the non-transport, sled dog, and captive wolf groups challenges the usefulness of spondylosis deformans as an indicator of transport related activities in archaeological specimens. Even if there is a relationship between the use of dogs for transport activities and the development of spondylosis deformans in the spines of those dogs, it seems that it would be inappropriate to use the disease in archaeological specimens to distinguish dogs used in transport from non-transport dogs, and in some cases even to distinguish dogs from wolves.

Non-transport dogs also had a significantly higher proportion of endplates affected with the disease than the other canids (non-transport versus sled dogs, X^2=7.87, p=0.0017; non-transport versus wolves, X^2=1361.49, p=0), meaning that individuals affected with the disease showed symptoms in a greater number of vertebrae than individuals in the sled dog or wolf group. In non-transport dogs 1468/7334 (20.02%) of endplates were affected as compared to 163/1026 (15.89%) in sled dogs, and 449/12981 (3.46%) in wolves. On average, an individual non-transport dog with the disease had 16.31 endplates affected in their spinal column. Interestingly, wolves and sled dogs had a similar degree of involvement in affected individuals--affected wolves had an average of 8.80 affected endplates/individual and affected sled dogs had an average of 8.08 affected endplates/individual. These results demonstrate a greater degree of involvement per individual among dogs not used for transport as compared to sled dogs or wolves, the latter two groups being similarly affected. Based on this, we might infer that in an archaeological context the disease would be more visible in an assemblage with high numbers of non-transport dogs as compared to sled dogs or wolves.

Both Arnold (1979:264) and Snyder (1994:214-216) have speculated that, in individual dogs, the presence of spondylosis deformans at multiple contiguous vertebrae might be related to transport activities. However, in this study all groups were found to have individuals affected with spondylosis deformans on multiple contiguous vertebrae. Counter to these earlier studies, the data presented here show that this pattern most frequently occurred among non-transport dogs, with 64/90 (71.11%) found to have multiple contiguous affected vertebrae compared to a frequency of 5/12 (41.67%) in sled dogs and 17/51 (33.33%) in wolves (Figure 6.2). Respectively, affected individuals had an average of 8.89, 7.00, and 9.47 contiguous affected vertebrae. In non-transport dogs 16/90 (17.78%) of individuals with spondylosis deformans had one or more entire vertebral section(s) (i.e.: cervical, thoracic, lumbar) affected by the disease. This occurred less in sled dogs (1/12 (8.33%) affected) and wolves (3/51 (5.88%) affected). Based on these results it seems that the presence of spondylosis deformans on 3 or more multiple contiguous vertebrae, or even affecting entire vertebral sections, is not useful in identifying dogs used in transport activities.

Across all groups the proportion of individuals with spondylosis deformans steadily increased as age increased (Figure 6.3). This trend was not surprising since spondylosis is a

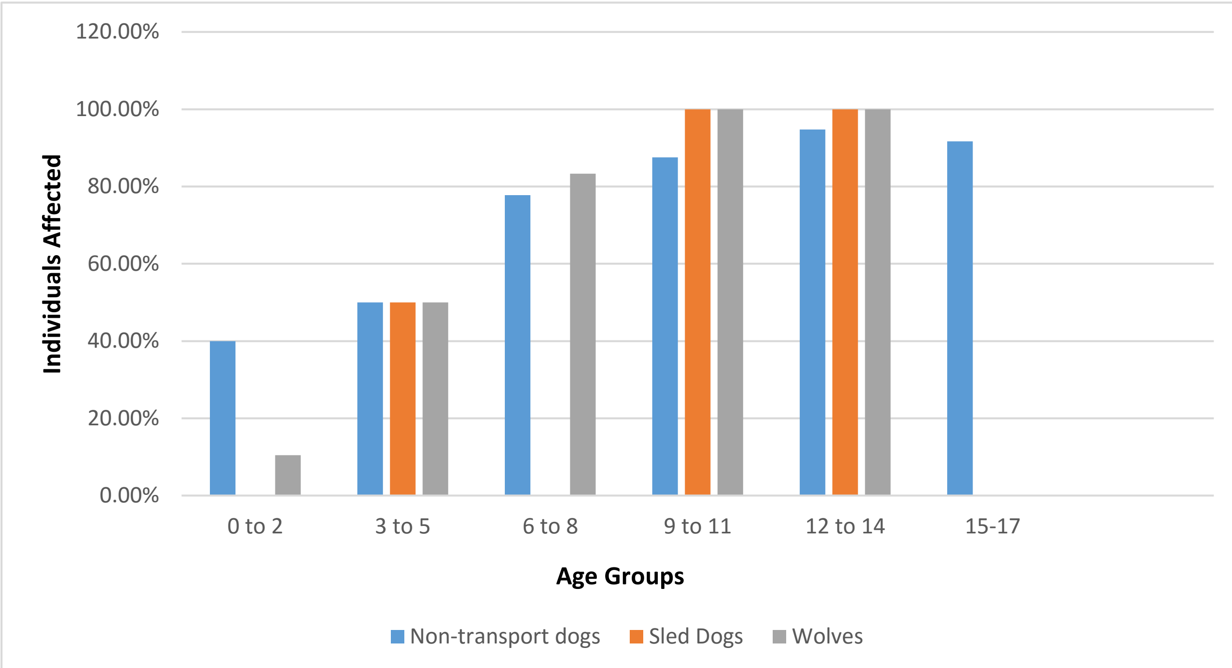
Figure 6.2: Frequency of multiple contiguous vertebrae (≥3) affected by spondylosis deformans in dogs and wolves



degenerative disease and other studies have shown a similar correlation between the occurrence of spondylosis deformans and aging in dogs (Carnier et al. 2004:86; Morgan 1967a:8; Morgan et al. 1967:62; Morgan et al. 1989:459; Read and Smith 1968:162). This same pattern also has been found in several other mammal species, including our own (Aufderheide and Rodriguez-Martin 1998:96; Baker and Brothwell 1980:131; Buikstra and Ubelaker 1994:123; Burt et al. 2013:57; Harris 1977:188; Jeffcott 1980; Kolmstetter et al. 2000:18; Meehan et al. 2009; Ortner and Putschar 1985:421).

This pattern may also explain the occurrence of higher rates of spondylosis deformans among dogs and captive wolves as compared to wild wolves. In the wild, few wolves live beyond four or five years of age (Fuller et al. 2003:175) though in rare cases they can reach up to fifteen years of age (Mech 2006:1482). Removed from the dangers of the wild, wolves living in

Figure 6.3: Spondylosis deformans in dogs and wolves of known age groups



captivity are more likely to survive to old age and can live as long as seventeen years (Mech 2006:1482). Among domestic dogs living in the care of humans the average lifespan is 10-13 years (Michell 1999:625; Proschowsky et al. 2003:72) though they too can live much longer. This study found that in all canid groups, half of all individuals aged 3-5 were already affected with the disease and that the proportion of individuals affected steadily increased after 5 years of age. Assuming that captivity extends the lives of wolves beyond the average life expectancy of individuals living in the wild, one would expect that the disease would be more common among the captive population than among wild individuals.

Age also appeared to have some effect on the severity of osteophytes observed in all groups. In each group there was a marked increase in stage 2 osteophytes after eight years of age, though it is important to note that the general occurrence of osteophytes increased as well. This was not, however, true of stage 3 osteophytes, which were rare and did not follow an age related pattern in any group.

From an archaeological perspective, these observations suggest that, rather than an indicator of usage in transport activities, spondylosis deformans in archaeological dogs may indicate the presence of older individuals within an assemblage. A high frequency of affected vertebrae or the presence of stage 2 osteophytes may further support such a conclusion. Furthermore, the presence of osteophytes in archaeological canids may also indicate some degree of human care, as canids are less likely to reach advanced ages when living in the wild. As this study has shown, canids living under human care experience higher rates of spondylosis than their wild counterparts.

Previous studies of domestic dogs (Carnier et al. 2004; Langeland and Lingaas 1995; Morgan 1967a:55-63; Morgan et al. 1989:459; Morgan et al. 1967:63) have argued that certain breeds may be genetically predisposed to developing spondylosis deformans. In this study, inbred wolves were found to have a higher frequency (22/81 (27.16%)) of the disease than their non-inbred counterparts (29/160 (18.13%)). Though the two populations did not differ significantly in frequency (X^2=2.07, p=0.1048) there is still a relatively high degree of probability (~90%) that these differences were not due to chance alone. This finding lends support to the suggestion that spondylosis deformans has a heritable genetic component. It also has important implications for archaeological contexts in which dogs living among relatively isolated human groups may have been subject to inbreeding or a small breeding pool.

Results from this study also found a correlation between body mass and the occurrence of spondylosis deformans in domestic dogs. When non-transport dogs were divided into size-related breed groups the frequency of spondylosis deformans steadily increased as body size increased

Table 6.1: Spondylosis deformans in non-transport dogs by size and percentage of individuals affected

	Small	Medium	Large
	(n=29)	(n=43)	(n=45)
	n (%)	n (%)	n (%)
Total	**16(55.17)**	**28(65.12)**	**41(91.11)**

(Table 6.1). Though small and medium dogs did not differ significantly in the frequency of individuals affected with the disease (X^2=0.28, p=0.3959), the rate at which large dogs were affected as compared to small and medium dogs was highly significant (small versus large breeds, p=0.0005; medium versus large breeds, p=0.004) suggesting that individuals of larger body mass are more prone to the disease than smaller individuals. This result is similar to the findings of Morgan (1967a:16, 55) who presented evidence that body mass may play a role in the development of the disease in some dogs.

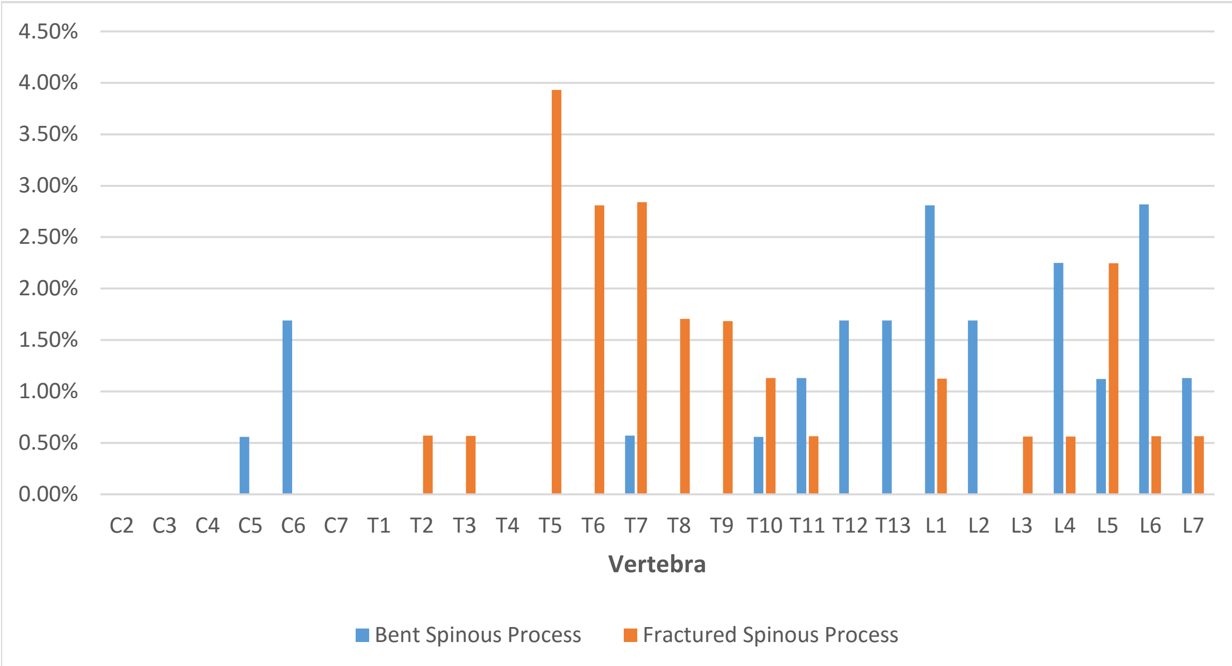
Across all three groups, individuals with fractured ribs appeared to have relatively high rates of spondylosis deformans. In non-transport dogs 4/7 (57.14%) individuals with fractured ribs also had the disease. Among sled dogs the frequency was 2/4 (50.00%), and in wolves 19/56 (33.93%) individuals with rib fractures had the disease. Though the sample sizes for both dog groups were very small, the elevated frequency of spondylosis deformans in individuals with rib fractures may indicate a link between physical trauma, particularly to the ribs, and the development of spondylosis deformans in the spine. This should be further evaluated in future studies where larger sample sizes of affected individuals are available.

Spinous process deformations: Deformations of the spinous processes were more common among wolves than in dogs. No clear pattern of deformation direction or location was observed in any of the canid groups analyzed. Non-transport dogs experienced very low rates of both bent processes (6/117 (5.13%)) and fractured processes (1/117 (0.85%)) and no individuals were affected by both fractures and bent processes. Sled dogs were not affected with bent spinous processes and only one individual experienced fractured processes (1/19 (5.26%)). The rates at which non-transport and sled dogs were affected with fractures did not differ significantly (p=0.2680). Dingoes were not affected by either form of process deformation, though it should be noted that only a small number of individuals were available for spinous process analysis.

Wolves were affected with both bent spinous processes (21/190 (11.05%)) and fractured processes (26/190 (13.68%)) at higher rates than either dog group and differed from non-transport dogs at a near-significant level (X^2=2.89, p=0.0759). Among affected wolves 6/47 (12.77%) individuals had both bent and fractured spinous processes in their spinal columns. Based upon similarities in the frequencies of bent, fractured, and bent and fractured spinous processes for this group it seems reasonable to speculate that bent processes may in fact be the result of internal micro-fractures or healed fractures rather than a separate etiology. Similarities in the vertebrae and vertebral regions affected also lend support to this interpretation (Figure 6.4).

All cases of bent or fractured processes among the wolves were found in the wild specimens, though due to the small sample size of captive wolves it is unclear whether the absence of deformities in this group is meaningful. However, in light of the observed differences between dogs and wolves, it seems reasonable to speculate that environmental differences may explain the higher rates of bent and fractured processes among wild wolves. This seems especially plausible if bent spinous processes are actually healed fractures, as wolves living in the wild may on average be more susceptible to spinal trauma than captive wolves or dogs living under the protective care of humans, at least in the samples analyzed here.

Figure 6.4: Distribution of bent and fractured spinous processes in wolves



The higher rates of both deformities among inbred wolves as compared to non-inbred wolves may lend further support to this speculation. Inbred wolves were affected with bent processes (12/80 (15.00%)) at nearly twice the rate as the non-inbred population (9/110 (8.18%). Though this difference was not statistically significant (X^2=1.95, p=0.1389) there is still a relatively high level of probability (~86.00%) that the two groups did not differ due to chance alone. Inbred wolves also suffered from a higher rate of fractured spinous processes (15/80 (18.75%)) than non-inbred wolves (11/110 (10.00%)) at a level near statistical significance (p=0.0832). Though it is possible that some unknown process could cause inbred wolves to suffer from bent spinous processes more frequently than non-inbred wolves, given the fracture rates in inbred wolves it seems far more likely that these differences can be explained by the environment in which each population lived. The inbred population lived in Sweden, a country with a population of nearly 10 million living in an area of about 450,295 sq. km (176, 000 sq.

mi) (~24 persons/sq. mile; Central Intelligence Agency 2016). In contrast, the wild population was almost entirely comprised of wolves from Alaska, a largely undeveloped state with an area of 570,640.95 sq. miles and a population of only 738,432 (about 1.2 persons/sq. mi) (United States Census Bureau 2016). Living in a more densely populated environment with many highly industrialized areas, the inbred population were likely at a much higher risk of injury due to traffic accidents and injuries from livestock than the Alaskan population. This is supported by the fact that 8/80 (10%) of the inbred wolves assessed were killed in traffic accidents.

There were not enough non-transport or sled dogs affected with spinous process deformities to evaluate the relationship between age and either pathology. However, in wolves there was a tendency for the occurrence of bent spinous processes to increase with age. This trend further supports the assertion that bent spinous processes may in fact represent healed fractures. In order for a bent process to occur, deformation would either have to take place during the osteological development of the individual (completed by about two years of age in wolves), or secondary to fracture and remodelling. However, when individuals two years of age or less were compared to those three and older, the latter group was affected at a significantly higher rate (age 2 or less=3/47 (6.38%), age 3 or older=6/23 (26.09%); p=0.051). The same was true when individuals four years of age or less were compared to those five and older (age 4 or less=5/59 (8.47%), age 5 or older=4/11 (36.36%); p=0.029). If bent processes were occuring earlier in life, then we should expect that young adult wolves would be affected at similar rates as older individuals. Instead, these findings indicate a positive relationship between aging and the development of bent processes, and support the hypotheiss that bent spinous processes represent healed fractures and not developmental deformities.

It is interesting to note that the rate and pattern of spinous process fractures in all groups was quite different than that observed by Warren (2004:95-138) in archaeological dogs from Illinois and the Southeastern United States where pack carrying is suspected. It is possible that these differences occurred due to different methods of recording deformations of the spinous processes. Warren appears to have counted a wider range of of deformities than were recorded in the present study, including any processes that did not lie in the midsagittal plane, apparent healed fractures, and any “deviations and unambiguous fractures”. How these broader parameters influenced Warren’s results and the differences observed between Warren’s results and the present study is not clear. However, in the present study dogs and wolves were affected at considerably lower rates than Warren’s study observed, even when bent processes were counted as fractures (compare Figures 6.5 & 6.6).

Among the dog groups there were not enough vertebrae affected to comment on patterning, but comparison between the wolf data from the present study and Warren’s data suggest that in general the same vertebrae tend to be affected by spinous process deformities though peak frequencies occurred in different vertebrae. Comparison of the patterning of affected vertebrae suggests that real differences exist between the two groups. Whether these differences occurred due to methodological differences or as the result of pack carrying, as suggested by Warren, remains unclear but is worthy of future investigation.

Though some intriguing patterns were observed in this study’s evaluation of canid spinous process deformations, during the course of anaylsis it became apparent that the methods devised for measuring and describing bent spinous processes did not adequately describe the full range of visible variation. Spinous processes which were clearly abnormal but did not meet

Figure 6.5: Frequency and distribution of spinous process deformations in dogs and wolves

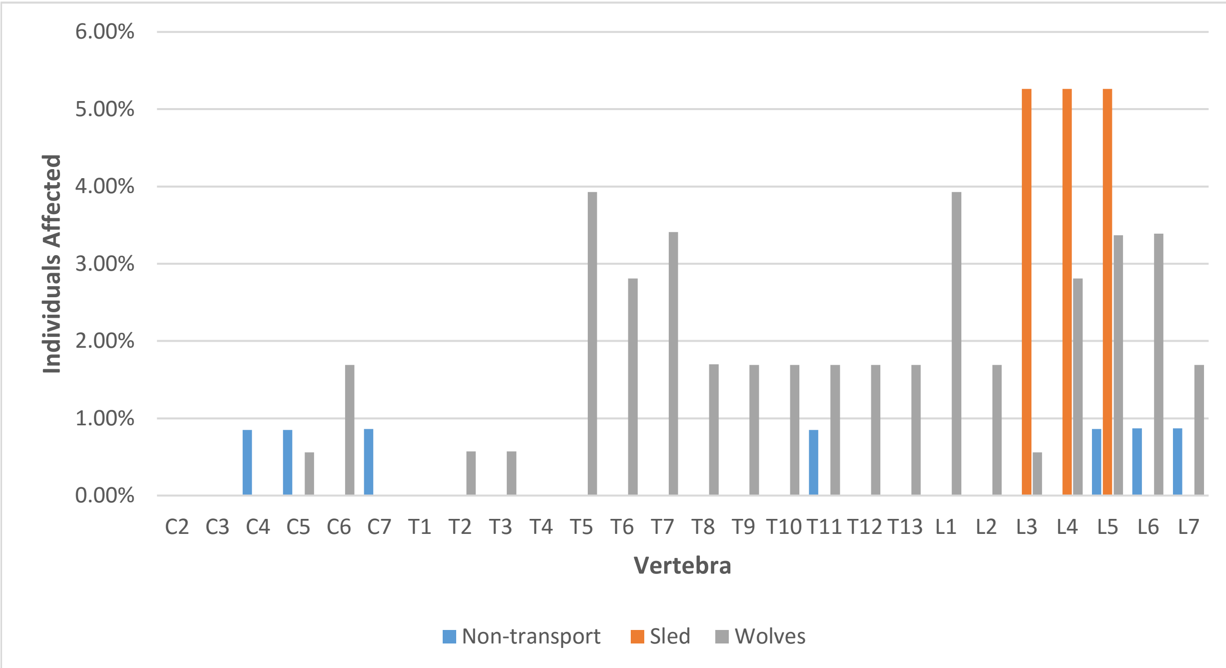
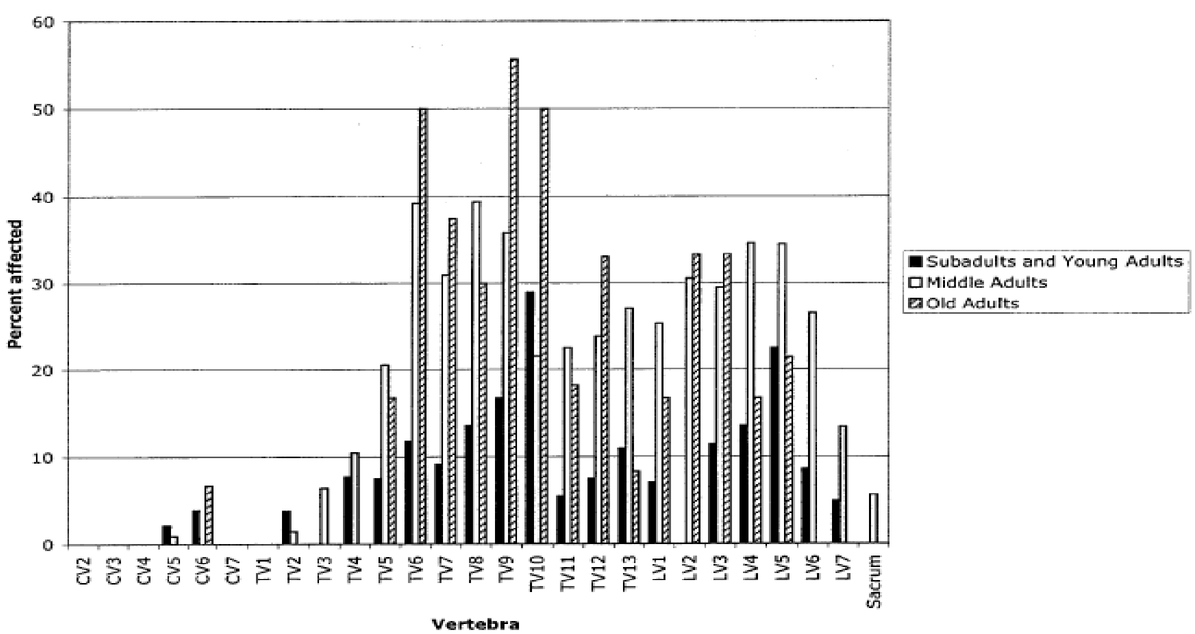


Figure 6.6: Frequency and distribution of spinous process deformations in archaeological dogs from Illinois and the Southeastern United States analyzed by Warren (2004: Figure 6.3)



the criteria laid out in the present study were frequently observed but could not be recorded. This included spinous processes which were anteriorly or posteriorly compressed, "S" shaped processes which deviated both left and right, processes which appeared twisted, processes with heavy or t-shaped distal tips, and quite commonly, processes which were bent just under 10 degrees in one direction. After analyzing more than 8,000 canid vertebrae it became quite clear that spinous processes can vary in a number of ways, many of which cannot be measured using linear methods like those employed in this study. Instead, it seems that it would be much more effective to utilize methods such as CT scanning or photogrammetry that would allow for three-dimensional analysis of spinous process deformations. This study has also suggested that bent spinous processes may be the result of healed fractures or micro-fractures, and CT scanning and x-rays would also be useful in testing this hypothesis.

Due to these methodological challenges it seems inappropriate to make conclusions regarding the usefulness of bent spinous processes as an indicator of transport activities among archaeological dogs. Though the results of this study suggest that wolves are more affected by this pathology than dogs, it is clear that we do not understand the normal range of shape variation for spinous processes in wild or domestic canids. Until this range of variation is established, it is difficult to clearly identify or describe abnormalities, thus making it impossible to systematically evaluate the relationship between spinous process deformations and a specific occupational etiology.

Chapter 7 : Conclusion

The use of domestic dogs for pulling or carrying loads is well documented in the recent and historic past in many parts of the world. Though it seems likely that dogs were utilized for transport in the prehistoric past, there is little artifactual evidence supporting such claims. Previous studies have suggested that certain skeletal pathologies may indicate that archaeological dogs were utilized for transport activities during their lives. The previous use of such indicators has largely been based upon archaeological observations and a single veterinary study of sled dogs used by the British Antarctic Survey. Because the occurrence of these skeletal indicators in modern dogs not involved in transport had not previously been systematically analyzed, their usefulness for identifying these activities archaeologically was unknown.

This study systematically analyzed the occurrence of spondylosis deformans and spinous process deformities in 155 modern dogs never used in transport activities, 19 sled dogs, and 241 wild wolves to evaluate the reliability of these pathologies as indicators of dog transport in archaeological assemblages. Specifically, this thesis posed five research questions, and the findings of my research relating to these questions are summarized below.

1. **At what rate does spondylosis deformans occur among modern wolves and in modern dogs that did not pull or carry loads?**

Spondylosis deformans occurs at high rates in modern dogs and wolves. This study found that 68.80% of dogs not used in transport activities were affected by the disease. Sled dogs were affected at a rate of 63.13% and were not significantly different from the non-transport population. In wild wolves, 17.98% of individuals were affected.

The disease did not affect juvenile individuals in either species but affected 71.07% of adult non-transport dogs and 26.45% of adult wild wolves. This is important to note, as the data shows that the frequency of this disease steadily increases with increased age in both species. This data does not support a relationship between spondylosis deformans and load bearing, but may in fact indicate the presence of old dogs in archaeological assemblages where high rates of osteophytes are found.

Though spondylosis deformans affected wild wolves at significantly lower rates than dogs, a similar proportion of captive wolves (76.92%%) had the disease. In other words, dogs and captive wolves are similarly affected by spondylosis deformans. This suggests that canids living with humans are more likely to develop the disease than their wild counterparts, likely because human care allows them to live longer than wolves in the wild. Archaeologically this has important implications for wolf remains affected by spondylosis and found within human cultural contexts—the presence of the disease may suggest some degree of human care, especially if a high proportion of endplates are affected.

It is also important to consider the frequencies at which individual vertebrae were affected for each group. In non-transport dogs 20.02% of all endplates had marginal osteophytes. This is a significantly higher proportion of affected endplates than in the sled dogs or wild wolves, which were affected at rates of 15.89%. and 3.46% respectively. Understanding the frequency of affected vertebrae within each analytic group potentially has important archaeological implications. Assuming that archaeological dogs and modern dog breeds have similar genetic predispositions to experiencing this disease, these results suggest that in an archaeological assemblage with relatively complete dog remains about 20% of the vertebral endplates should be affected with spondylosis deformans in a population of mostly adult individuals. Where wild wolves are present in an assemblage, we should expect to see about 3-5% (4.94% if only adults are present) of endplates affected.

2. **At what rate are modern dogs and wolves affected with marginal osteophytes on multiple contiguous vertebrae?**

Individuals affected with spondylosis deformans on three or more multiple contiguous vertebrae were relatively common for individuals with the disease in all canid groups. This study found that 71.11% of modern non-transport dogs, 41.67% of sled dogs, and 33.33% of wolves with spondylosis deformans had three or more contiguous vertebrae affected by marginal osteophytes. In non-transport dogs, 17.78% of individuals with spondylosis deformans had osteophytes on every vertebra in one or more vertebral region. This occurred less in sled dogs (8.33%) and wolves (5.88%) but was observed in both groups.

The rate of individuals with multiple contiguous affected vertebrae was unsurprising, given the association between spondylosis deformans and increased age in all canid groups. Results of this study show that as individuals age they are not only more likely to develop the disease, but the number of vertebrae affected in an individual also increases with age, thereby increasing the likelihood that multiple contiguous vertebrae will become affected.

3. **Is spondylosis deformans a reliable indicator of load bearing in dogs or more likely a product of natural variation, ageing, or genetic causes?**

Based upon the results of this study, spondylosis deformans is not a reliable indicator of load bearing in dogs. This study found no relationship between the use of dogs for pulling or carrying loads and the growth of marginal osteophytes characteristic of the disease. This study has shown that spondylosis deformans commonly affects dogs, regardless of their use in transport activities, and to a lesser extent wild wolves, and that increased age, body size, genetic factors, and living environment all play a role in pathogenesis.

Even if the mechanical stresses of load pulling or carrying do contribute to the growth of marginal osteophytes, given the prevalence in modern dogs and numerous predisposing factors associated with the disease, it does not seem possible to distinguish between occupational and natural etiologies in archaeological specimens. Though Warren (2004) has suggested that pack carrying may cause a pattern of osteophyte distribution that differs from the typical pattern seen in modern dogs, this study has suggested that other intrinsic factors also may explain these differences.

4. **At what rate do bent or fractured spinous processes occur among modern wolves and dogs not used for traction?**

Bent spinous processes were more common in wolves than in modern dogs not used for transport activities. Wild wolves were affected by bent processes at a rate of 11.80% and 14.61% were affected with spinous process fractures. Of those wolves with spinous process deformations, 12.77% had both bent and fractured processes in their spinal columns. Bent spinous processes occurred at low rates in dogs. Only 5.13% of non-transport dogs were affected with bent processes and 7.69% were affected by spinous process fractures. There were no cases of both bent and fractured spinous processes in an individual dog's vertebral column.

In wolves the rate at which bent spinous processes occurred and the rate at which fractured spinous processes occurred were similar, as was the rate at which these deformations co-occurred in individuals. The same was true in dogs. Based upon this pattern I suggest that bent spinous processes may be cases of micro-fractures or well healed fractures that cannot be observed macroscopically. Future research using CT scanning or X-ray would be useful in testing this hypothesis.

5. **Are bent or fractured spinous processes a reliable indicator of load bearing in dogs?**

It is not clear if bent or fractured spinous processes are a reliable indicator of load bearing in dogs. Both deformities were observed in the present study, and were more frequent among wolves than in either dog group. Though comparison to previous studies suggests real differences between the pattern and frequency of spinous process deformities in some archaeological dogs and modern dogs and wolves, the extent to which the differing methods of identifying and counting deformities influenced these differences is uncertain.

The methods developed for measuring and quantifying bent processes in this study proved inadequate for documenting the total natural range of variation that occurs with spinous process deformations in dogs and wolves. Though the initial goals of this study were not fully achieved, valuable insights were gained. First, the data obtained suggests that spinous processes which are bent by 10 degrees or more to the left or right of the midsagittal plane are relatively rare in dogs, regardless of their use in pulling loads, and are more likely to occur in wild wolves though also at low rates.

Second, the methodological limitations and qualitative data obtained demonstrate the need for a more comprehensive analysis of the natural range of variation for spinous process deformities among populations not used in transport activities. In the process of analysis, it became clear that spinous processes that deviated from the midsagittal plane by less than ten degrees are not unusual and occur in a variety of forms. The occurrence rate of lesser deviations, or deviations which are not easily captured using these methods, needs to be established in order to understand the natural range of variation in dogs and wolves. Until that range is defined, it is not clear how much variation archaeologists should allow for when identifying spinous processes as bent, compressed, or thickened.

Lastly, attempts at comparative analysis with previous archaeological studies have illustrated the need for consistent methods of identifying, describing, quantifying, and comparing spinous process deviations. Methodological differences made comparison between previous archaeological studies and the present study difficult, and in some cases impossible. In some studies, deviations of the spinous processes were broadly defined and almost certainly included incidences that were observed but not recorded in the present study because they did not fit the parameters defined for this analysis. Other studies mention the occurrence of bent, flattened, compressed, thickened or otherwise abnormal spinous processes, but provide little or no visual documentation of the elements observed, or metrics for describing or quantifying the extent of the abnormality. While physical descriptors are useful, they are subjective and limit the potential for future comparisons between studies.

Final Conclusions

This study has shown that spondylosis deformans is not a reliable indicator of load pulling or carrying in dogs. However, results suggest that the disease may indicate the presence of older dogs and wolves when it is found at high frequencies in archaeological assemblages. Evaluation of the use of bent, fractured, or otherwise deformed spinous processes as an indicator of dog transport was inconclusive. Results of this study suggest that future research regarding the cause of bent spinous processes is needed in order to better understand the natural range of deviations and to improve archaeological methods for recording and interpreting such deformities.

References Cited

Allen, Glover M.

1920 *Dogs of the American Aborigines*. Bulletin of the Museum of Comparative Zoology Vol. 63, No. 9. Harvard University, Cambridge.

American Kennel Club,

2016 Dog Breeds. Electronic document, http://www.akc.org/dog-breeds/, accessed January 30, 2016.

Arnold, Charles D.

1979 Possible Evidence of Domestic Dog in a Paleoeskimo Context. *Arctic* 32(3): 263-265.

Aufderheide, Arthur C. and Conrado Rodriguez-Martin

2005 *The Cambridge Encyclopedia of Human Paleopathology.* Reprinted. Originally published 1998. Cambridge University Press, Cambridge.

Baker, J. and D. Brothwell

1980 *Animal Diseases in Archaeology*. Academic Press, London.

Bellars, A.R.M.

1969 Veterinary Studies of the British Antarctic Survey's Sledge Dogs: I. Survey of Diseases and Accidents. *British Antarctic Survey Bulletin* 21:1-18.

Bellars, A.R.M. and M.F. Godsall

1969 Veterinary Studies of the British Antarctic Survey's sledge dogs: II. Occupational Osteoarthritis. *British Antarctic Survey Bulletin* 22:15-38.

Benecke, Norbert

1987. Studies on Early Dog Remains from Northern Europe. *Journal of Archaeological Science* 14(1):31-49.

Bleed, Peter

2006. Living in the Human Niche. *Evolutionary Anthropology* 15(1):8-10.

Bogoras, Waldemar

1909 *The Chukchee*, Vol. 11. EJ Brill Limited.

Bozell, J. R

1988 Changes in the Role of the Dog in Protohistoric-historic Pawnee Culture. *Plains Anthropologist* 33(119):95-111.

Brown, Sarah K., Christyann M. Darwent, Benjamin N. Sacks

2013 Ancient DNA Evidence for Genetic Continuity in Arctic Dogs. *Journal of Archaeological Science* 40:1279-1288.

Brown, SK., CM Darwent, EJ Wictum, BN Sacks

2015 Using Multiple Markers to Elucidate the Ancient, Historical and Modern Relationships among North American Arctic Dog Breeds. *Heredity* 115:488–495.

Burt, Nicole M., Dyan Semple, Kathryn Waterhouse, and Nancy C. Lovell

2013 *Identification and Interpretation of Joint Disease in Paleopathology and Forensic Anthropology*. Charles C. Thomas, Springfield.

Carnier, P., L. Gallo, E. Sturaro, P. Piccinini, & G. Bittante.

2004 Prevalence of Spondylosis Deformans and Estimates of Genetic Parameters for the Degree of Osteophytes Development in Italian Boxer Dogs. *Journal of Animal Science* 82(1), 85-92.

Central Intelligence Agency of the United States of America

2016 The World Factbook. Electronic document, https://www.cia.gov/library/publications/the-world-factbook/geos/sw.html, accessed May 10, 2016.

Chernetsov, Vallerii Nikolaevitch, and W. Moszynska.

1974 *Prehistory of Western Siberia.* No. 9. McGill-Queen's Press-MQUP.

Clutton-Brock, Juliet

1995 Origins of the Dog: Domestication and early history. In *The Domestic Dog: Its Evolution, Behaviour and Interactions with People*, edited by James Serpell, pp. 7-20. Cambridge University Press, Cambridge.

Crapon de Caprona, Marie-Dominique and Peter Savolainen

2013 Extensive Phenotypic Diversity among South Chinese Dogs. *ISRN Evolutionary Biology* 2013(3):1-8.

Crockford, Susan J., and Yaroslav V. Kuzmin

2012 Comments on Germonpré et al., Journal of Archaeological Science 36, 2009 "Fossil dogs and wolves from Palaeolithic sites in Belgium, the Ukraine and Russia: Osteometry, ancient DNA and stable isotopes", and Germonpré, Lázkičková-Galetová, and Sablin, Journal of Archaeological Science 39, 2012 "Palaeolithic dog skulls at the Gravettian Předmostí site, the Czech Republic". *Journal of Archaeological Science* 39:2797-2801.

Damas, David (editor)

1984 *Handbook of North American Indians*, Vol. V. Smithsonian Institution, Washington D.C.

Davis, Leslie B. and Emmett Stallcop

1965 *The Keaster Site (24PH401): A Stratified Bison Kill Occupation in the Missouri Breaks Area of North Central Montana*. Montana Archaeological Society, Memoir No. 2.

Davis, Simon J.M., and Francois R. Valla

1978 Evidence for Domestication of the Dog 12,000 years ago in the Natufian of Israel. *Nature* 276:608-610.

De Lavigne, Guillaume

2014 *The Draft Dog Past and Present.* Published by author, *Lulu.com*

Ding, Z. L., M. Oskarsson, A. Ardalan, H. Angleby, L. G. Dahlgren, C. Tepeli, E. Kirkness, P. Savolainen, and Y.P. Zhang.

2011 Origins of Domestic Dog in Southern East Asia is Supported by Analysis of Y-chromosome DNA. *Heredity* 108(5):507-514.

Drake, Abby Grace, Michael Coquerelle, and Guillaume Colombeau

2015 3D Morphometric Analysis of Fossil Canid Skulls Contradicts the Suggested Domestication of Dogs During the Late Paleolithic. *Scientific Reports* 5.

Druzhkova, Anna S., Olaf Thalmann, Vladimir A. Trifonov, Jennifer A. Leonard, Nadezhda V. Vorobieva, Nikolai D. Ovodov, Alexander S. Graphodatsky, and Robert K. Wayne

2013 Ancient DNA Analysis Affirms the Canid from Altai as a Primitive Dog. *PLOS ONE* 8(3): e57754.

Dyck, Ian G.

1977 *The Harder Site: A Middle Period Bison Hunter's Campsite in the Northern Great Plains*. PhD Dissertation, Department of Anthropology, University of Alberta, Edmonton.

Federation Cynologique Internationale

2016 FCI breeds nomenclature. Electronic document, http://www.fci.be/en/Nomenclature/, accessed January 30, 2016.

Fedorova, N.V.,

2000 Olen', sobaka, kulaiskii fenomen i legenda o Sikhirtia. In Golovnev, A.V. (Ed.). *Drevnisti Iamala*, Vol. 1., pp. 54-66. Ekaterinburg-Salekhard, UrO RAN.

Frantz, Laurent A. F., Victoria E. Mullin, Maud Pionnier-Capitan, Ophélie Lebrasseur, Morgane Ollivier, Angela Perri, Anna Linderholm, Valeria Mattiangeli, Matthew D. Teasdale, Evangelos A. Dimopoulos, Anne Tresset, Marilyne Duffraisse, Finbar McCormick, László Bartosiewicz, Erika Gál, Éva A. Nyerges, Mikhail V. Sablin, Stéphanie Bréhard, Marjan Mashkour, Adrian

Bălășescu, Benjamin Gillet, Sandrine Hughes, Olivier Chassaing, Christophe Hitte, Jean-Denis Vigne, Keith Dobney, Catherine Hänni, Daniel G. Bradley and Greger Larson

2016 Genomic and Archaeological Evidence Suggest a Dual Origin of Domestic Dogs. *Science* 352(6290):1228-1231.

Fuller, Todd K., L. David Mech, Jean Fitts Cochrane

2003 Wolf Population Dynamics. In *Wolves: Behavior, Ecology, and Conservation,* edited by L. David Mech and Luigi Boitani, pp.161-191. University of Chicago Press, Chicago.

Germonpré, Mietje, Martina Lázničková-Galetová, Robert J. Losey, Jannikke Räikkönen, and Mikhail V. Sablin.

2015 Large Canids at the Gravettian Předmostí Site, the Czech Republic: The Mandible. *Quaternary International* 359:261-279.

Germonpré, Mietje, Martina Lázničková-Galetová, and Mikhail V. Sablin

2012 Palaeolithic Dog Skulls at the Gravettian Předmostí Site, the Czech Republic. *Journal of Archaeological Science* 39(1):184-202.

Germonpré, Mietje, Mikhail V. Sablin, Rhiannon E. Stevens, Robert E.M Hedges, Michael Hofreiter, Mathias Stiller, Viviane R. Després

2009 Fossil Dogs and Wolves from Palaeolithic Sites in Belgium, the Ukraine and Russia: Osteometry, Ancient DNA and Stable Isotopes. *Science* 36(2):473-490.

Gregg, M. L.

1987 *Archaeological Excavation at the Naze Site (32SN246)*. Department of Anthropology, University of North Dakota. Submitted to the U.S. Bureau of Reclamation.

Grinnell, George Bird

1920 *When Buffalo Ran*. Yale University Press, New Haven.

Gusev, A.V.

2014. Kompleks Predmetov, Sviazannykhs Olenevodstvom, po Materialam Sviatilishcha Ust'-Polui (Nizhnee Priob'e). Ural'skii Istoricheskii Vestnik 2(43):53-62.

Hansen, Hans-Jörgen

1952 A Pathologic-anatomical Study on Disc Degeneration in Dog: With Special Reference to the So-called Enchondrosis Intervertebralis. *Acta Orthopaedica Scandinavica* 23(sup11):1-130, DOI: 10.3109/ort.1952.23.suppl-11.01.

Harris, Stephen

1997 Spinal Arthritis (Spondylosis Deformans) in the Red Fox, *Vulpes*, with Some Methodology of Relevance to Zooarchaeology. *Journal of Archaeological Science* 4(2):183-195.

Helskog, Knut

2010 Reindeer Corrals 4700-4200 BC: Myth or Reality? *Quaternary International* 238 (1):25-34.

Henderson, Norman

1994 Replicating Dog Travois Travel on the Northern Plains. *The Plains Anthropologist* 145-159.

Hughes, Charles C.

1984 Saint Lawrence Island Eskimo. In *Arctic,* edited by David Damas, pp. 262-27. *Handbook of North American Indians,* Vol. 5, William C. Sturtevant, general editor, Smithsonian Institution, Washington D.C.

Jeffcott, L.B.

1979 Radiographic Features of the Normal Equine Thoracolumbar Spine. *Veterinary Radiology* 20:140-7.

1980 Disorders of the Thoracolumbar Spine of the Horse - a Survey of 443 Cases. *Equine Veterinary Journal* 12(4):197-210.

Kennedy, Kenneth A.R.

1989 Skeletal Markers of Occupational Stress. In *Reconstruction of Life from the Skeleton.* Edited by Mehmet Yasar Iscan and Kenneth A.R. Kennedy, pp.129-160. Alan R. Liss, Inc. New York.

Kleivan, Inge

1984 West Greenland Before 1950. In *Arctic,* edited by David Damas, pp. 595-621. *Handbook of North American Indians,* Vol. 5, William C. Sturtevant, general editor, Smithsonian Institution, Washington D.C.

Kolmstetter, Christine, Linda Munson, and Edward C. Ramsay

2000 Degenerative Spinal Disease in Large Felids. *Journal of Zoo and Wildlife Medicine* 31(1):15-19.

Langeland, J M. and F. Lingaas

1995 Spondylosis Deformans in the Boxer: Estimates of Heritability. *Journal of Small Animal Practice* 36, 166-169.

Lantis, Margaret

1984 Nunivak Eskimo. In *Arctic,* edited by David Damas, pp. 209-223. *Handbook of North American Indians,* Vol. 5, William C. Sturtevant, general editor, Smithsonian Institution, Washington D.C.

Larson, Greger, Elinor K. Karlsson, Angela Perri, Matthew T. Webster, Simon Y. W. Ho, Joris Peters, Peter W. Stahl, Philip J. Piper, Frode Lingaas, Merete Fredholm, Kenine E. Comstock, Jaime F.Modiano, Claude Schelling, Alexander I. Agoulnik, Peter A. Leegwater, Keith Dobney, Jean-Denis Vigne, Carles Vilà, Leif Andersson, and Kerstin Lindblad-Toh

2012 Rethinking Dog Domestication by Integrating Genetics, Archeology, and Biogeography. *Proceedings of the National Academy of Sciences* 109(23):8878-8883.

Lee, Esther J., D. Andrew Merriwether Alexei K. Kasparov, Pavel A. Nikolskiy, Marina V. Sotnikova, Elena Yu Pavlova, Vladimir V. Pitulko

2015 Ancient DNA Analysis of the Oldest Canid Species from the Siberian Arctic and Genetic Contribution to the Domestic Dog. PLoS ONE 10(5): e0125759. doi:10.1371/journal.pone.0125759

Leonard, Jennifer A., Robert K. Wayne, Jane Wheeler, Raúl Valadez, Sonia Guillén, Carles Vilà

2002 Ancient DNA Evidence for Old World Origin of New World Dogs. *Science* 298(5598):1613-1616.

Levine, Marsha A.

2005 Domestication and Early History of the Horse. In *The Domestic Horse: The Origins, Development and Management of its Behavior,* edited by Daniel S. Mills and Sue M. McDonnell, pp. 5-22. Cambridge University Press, Cambridge.

Levine, Marsha A., G. Bailey, Katherine E. Whitwell, and Leo B. Jeffcott

2000 Palaeopathology and Horse Domestication: The Case of Some Iron Age Horses from the Altai Mountains, Siberia. In *Human Ecodynamics. Symposia of the Association for Environmental Archaeology,* edited by G. Bailey, R. Charles and N. Winder, pp. 123-133. Oxbow Books.

Lindblad-Toh, Kerstin, Claire M Wade, Tarjei S. Mikkelsen, Elinor K. Karlsson, David B. Jaffe, Michael Kamal, Michele Clamp, Jean L. Chang, Edward J. Kulbokas III, Michael C. Zody, Evan Mauceli, Xiaohui Xie, Matthew Breen, Robert K. Wayne, Elaine A. Ostrander, Chris P. Ponting, Francis Galibert, Douglas R. Smith, Pieter J. deJong, Ewen Kirkness, Pablo Alvarez, Tara Biagi, William Brockman, Jonathan Butler, Chee-Wye Chin, April Cook, James Cuff, Mark J. Daly, David DeCaprio, Sante Gnerre, Manfred Grabherr, Manolis Kellis, Michael Kleber, Carolyne Bardeleben, Leo Goodstadt, Andreas Heger, Christophe Hitte, Lisa Kim, Klaus-Peter Koepfli, Heidi G. Parker, John P. Pollinger, Stephen M. J. Searle, Nathan B. Sutter, Rachael Thomas, Caleb Webber, Jennifer Baldwin, Adal Abebe, Amr Abouelleil, Lynne Aftuck, Mostafa Ait-zahra, Tyler Aldredge, Nicole Allen, Peter An, Scott Anderson, Claudel Antoine, Harindra Arachchi, Ali Aslam, Laura Ayotte, Pasang Bachantsang, Andrew Barry, Tashi Bayul, Mostafa Benamara, Aaron Berlin, Daniel Bessette, Berta Blitshteyn, Toby Bloom, Jason Blye, Leonid Boguslavskiy, Claude Bonnet, Boris Boukhgalter, Adam Brown, Patrick Cahill, Nadia Calixte, Jody Camarata, Yama Cheshatsang, Jeffrey Chu, Mieke Citroen, Alville Collymore, Patrick Cooke, Tenzin Dawoe, Riza Daza, Karin Decktor, Stuart DeGray, Norbu Dhargay, Kimberly Dooley, Kathleen Dooley, Passang Dorje, Kunsang Dorjee, Lester Dorris, Noah Duffey, Alan Dupes, Osebhajajeme Egbiremolen, Richard Elong, Jill Falk, Abderrahim Farina, Susan Faro,

Diallo Ferguson, Patricia Ferreira, Sheila Fisher, Mike FitzGerald, Karen Foley, Chelsea Foley, Alicia Franke, Dennis Friedrich, Diane Gage, Manuel Garber, Gary Gearin, Georgia Giannoukos, Tina Goode, Audra Goyette, Joseph Graham, Edward Grandbois, Kunsang Gyaltsen, Nabil Hafez, Daniel Hagopian, Birhane Hagos, Jennifer Hall, Claire Healy, Ryan Hegarty, Tracey Honan, Andrea Horn, Nathan Houde, Leanne Hughes, Leigh Hunnicutt, M. Husby, Benjamin Jester, Charlien Jones, Asha Kamat, Ben Kanga, Cristyn Kells, Dmitry Khazanovich, Alix Chinh Kieu, Peter Kisner, Mayank Kumar, Krista Lance, Thomas Landers, Marcia Lara, William Lee, Jean-Pierre Leger, Niall Lennon, Lisa Leuper, Sarah LeVine, Jinlei Liu, Xiaohong Liu, Yeshi Lokyitsang, Tashi Lokyitsang, Annie Lui, Jan Macdonald, John Major, Richard Marabella, Kebede Maru, Charles Matthews, Susan McDonough, Teena Mehta, James Meldrim, Alexandre Melnikov, Louis Meneus, Atanas Mihalev, Tanya Mihova, Karen Miller, Rachel Mittelman, Valentine Mlenga, Leonidas Mulrain, Glen Munson, Adam Navidi, Jerome Naylor, Tuyen Nguyen, Nga Nguyen, Cindy Nguyen, Thu Nguyen, Robert Nicol, Nyima Norbu, Choe Norbu, Nathaniel Novod, Tenchoe Nyima, Peter Olandt, Barry O'Neill, Keith O'Neill, Sahal Osman, Lucien Oyono, Christopher Patti, Danielle Perrin, Pema Phunkhang, Fritz Pierre, Margaret Priest, Anthony Rachupka, Sujaa Raghuraman, Rayale Rameau, Verneda Ray, Christina Raymond, Filip Rege, Cecil Rise, Julie Rogers, Peter Rogov, Julie Sahalie, Sampath Settipalli, Theodore Sharpe, Terrance Shea, Mechele Sheehan, Ngawang Sherpa, Jianying Shi, Diana Shih, Jessie Sloan, Cherylyn Smith, Todd Sparrow, John Stalker1, Nicole Stange-Thomann, Sharon Stavropoulos, Catherine Stone, Sabrina Stone, Sean Sykes, Pierre Tchuinga, Pema Tenzing, Senait Tesfaye, Dawa Thoulutsang, Yama Thoulutsang, Kerri Topham, Ira Topping, Tsamla Tsamla, Helen Vassiliev, Vijay Venkataraman, Andy Vo, Tsering Wangchuk, Tsering Wangdi, Michael Weiand, Jane Wilkinson, Adam Wilson, Shailendra Yadav, Shuli

Yang, Xiaoping Yang, Geneva Young, Qing Yu, Joanne Zainoun, Lisa Zembek and Andrew Zimmer for Broad Sequencing Platform members and Eric S. Lander

Genome Sequence, Comparative Analysis and Haplotype Structure of the Domestic Dog. *Nature* 438(7069):803-819.

Loovers, Jan Peter Laurens.

2015 Dog Craft: A History of Gwich'in and Dogs in the Canadian North. *Hunter Gatherer Research* 1(4):387-419.

Lowie, Robert H.

1954 *Indians of the Plains.* The Natural History Press, Garden City, New York.

Mannermaa, Kristiina, Pirkko Ukkonen & Suvi Viranta

2014 Prehistory and Early History of Dogs in Finland. *Fennoscandia archaeologica* XXXI:25-44.

Matsui, Akira

2008 *Fundamentals of Zooarchaeology in Japan.* Kyoto University Press, Kyoto.

Mech, L.D.

2006 Estimated Age Structure of Wolves in Northeastern Minnesota. *Journal of Wildlife Management* 70(5):1481-1483.

Meehan, L., S. Dyson, and R. Murray

2009 Radiographic and Scintigraphic Evaluation of Spondylosis in the Equine Thoracolumbar Spine: A Retrospective Study. *Equine Veterinary Journal* 41(8):800-807.

Michell, A.R.

1999 Longevity of British Breeds of Dog and its Relationships with Sex, Size, Cardiovascular Variables and Disease. *The Veterinary Record* 145(22):625-629.

Millar, J.F.V.

1978 *The Gray Site: An Early Plains Burial Ground*, Vol. I and II, Parks Canada Manuscript, No. 304.

Morey, Darcy F.

2010 *Dogs: Domestication and the Development of a Social Bond*. Cambridge University Press, New York.

2014 In search of Paleolithic Dogs: A Quest with Mixed Results. *Journal of Archaeological Science* 52:300-307.

Morey, Darcy F. and Kim Aaris-Sorensen

2002 Paleoeskimo Dogs of the Eastern Arctic. *Arctic* 55(1):44-56.

Morey, Darcy F. and Rujana Jeger

2015 Paleolithic Dogs: Why Sustained Domestication Then? *Journal of Archaeological Science: Reports* 3:420-428.

Morgan, J. P.

1967a Spondylosis Deformans in the Dog: A Morphologic Study with Some Clinical and Experimental Observations. *Acta Orthopaedica* 38(sup96):1-88.

1967b Spondylosis Deformans in the Dog: Its Radiographic Appearance. *Veterinary Radiology 8*(1):17-22.

Morgan Joseph P., K. Hansson and T. Miyabayashi

1989 Spondylosis Deformans in the Female Beagle Dog: A Radiographic Study. *Journal of Small Animal Practice* 30(8):457-460.

Morgan, J. P., G. Ljunggren and Rosemary Read

1967 Spondylosis Deformans (Vertebral Osteophytosis) in the Dog. *Journal of Small Animal Practice* 8(2):57-66.

Napierala, Hannes and Hans-Peter Uerpmann

2012 A 'New' Palaeolithic Dog from Central Europe. *International Journal of Osteoarchaeology* 22(2):127-137.

Olsen, Stanley J.

1985 *Origins of the Domestic Dog: The Fossil Record.* The University of Arizona Press, Tucson.

Ortner, Donald J. and Walter G.J. Purschar

1985 Identification of Pathological Conditions in Human Skeletal Remains. Originally published 1981, *Smithsonian Contributions to Anthropology* No. 28, Smithsonian Institution, Washington, D.C.

Pang, Jun-Feng, Cornelya Kluetsch, Xiao-Ju Zou, Ai-bing Zhang, Li-Yang Luo, Helen Angleby, Arman Ardalan, Camilla Ekström, Anna Sköllermo, Joakim Lundeberg, Shuichi Matsumura, Thomas Leitner, Ya-Ping Zhang and Peter Savolainen

2009 mtDNA Data Indicate a Single Origin for Dogs South of Yangtze River, Less than 16,300 years ago, from Numerous Wolves. *Molecular Biology and Evolution* 26(12):2849-2864.

Pitulko, V.V., Kasparov, A.K.

2016. Holocene Dog Bones from the Zhokhov Site (East Siberian Arctic) and the Question of the Reliability of Identification of Early Canis familiaris from Archaeological Excavations. In *The Link of Times, Stratum Plus,* no. 1. Edited by L.B. Vishnyatsky and S.I. Covalenco, Pp. 171-207.

Proschowsky, Helle Friis, Helene Rugbjerg, and Annette Kjaer Ersboll

2003 Mortality of Purebred and Mixed-breed Dogs in Denmark. *Preventive Veterinary Medicine* 58, 63-74.

Räikkönen, J., A. Bignert, P. Mortensen and B. Fernholm

2006 Congenital Defects in a Highly Inbred Wild Wolf Population (Canis lupus). *Mammalian Biology-Zeitschrift für Säugetierkunde 71*(2):65-73.

Räikkönen, Jannikke, John A. Vucetich, Rolf O. Peterson, and Michael P. Nelson.

2009 Congenital Bone Deformities and the Inbred Wolves (Canis lupus) of Isle Royale. *Biological Conservation* 142(5): 1025-1031.

Read, Rosemary and R. N. Smith

1968 A Comparison of Spondylosis Deformans in the English and Swedish Cat and in the English Dog. *Journal of Small Animal Practice* 9(4):159-166.

Sablin, Mikhail V. and Gennady A. Khlopachev

2002 The Earliest Ice Age Dogs: Evidence from Eliseevichi 1. *Current Anthropology* 43(5):795-799.

Saladin d'Anglure, Bernard

1984 Inuit of Quebec. In *Arctic,* edited by David Damas, pp. 476-507. *Handbook of North American Indians,* Vol. 5, William C. Sturtevant, general editor, Smithsonian Institution, Washington D.C.

Samar, A.P.

2010 *Traditional Dog Breeding of the Nanai*. Russian Academy of Sciences Far-Eastern Branch. Institute of History, Archaeology and Ethnography of Peoples of the Far East, Vladivostok.

Savolainen, Peter

2007 Domestication of Dogs. In *The Behavioural Biology of Dogs*, edited by Per Jensen, pp. 21-37. CABI, Wallingford, Oxfordshire.

Savolainen, Peter, Ya Ping Zhang, Jing Luo, Joakim Lundeberg, and Thomas Leitner

2002 Genetic Evidence for an East Asian Origin of Domestic Dogs. *Science* 298(5598):1610-1613.

Schulting, Rick

1994 The Hair of the Dog: The Identification of a Coast Salish Dog-Hair Blanket from Yale, British Columbia. *Canadian Journal of Archaeology* 18(1994):57-76.

Shipman, Pat

2011 *The Animal Connection: A New Perspective on What Makes Us Human*. W.W. Norton, New York.

Snyder, Lynn M.

1991 Barking Mutton: Ethnohistoric, Ethnographic, Archaeological, and Nutritional Evidence Pertaining to the Dog as a Native American Food Resource on the Plains. In *Beamers, Bobwhites, and Blue-Points: Tributes to the Career of Paul W. Parmalee,* Vol. 23*,* edited by James R. Purdue, Walter E. Klippel, and Bonnie W. Styles, pp. 359-375. Illinois State Museum Scientific Papers, Springfield.

1995 Assessing the Role of the Domestic Dog as a Native American Food Resource in the Middle Missouri Subarea AD 1000-1840. PhD dissertation, Department of Anthropology, University of Tennessee, Knoxville.

Thalmann, O., B. Shapiro, P Cui, V.J. Schuenemann, S.K. Sawyer, D.L. Greenfield, M.B. Germonpre, M.V. Sablin, F. Lopez-Giraldez, S. Domingo-Roura, H. Napierla, H.P. Uerpmann, D.M. Loponte, A.A. Acosta, L. Giemsch, R.W. Schmitz, B. Worthington, J. E. Buikstra, A. Druzhkova, A.S. Graphodatsky, N.D. Ovodov, N. Wahlberg, A.H. Freedman, R.M. Scweizer, K.-P. Koepfli, J.A. Leonard, M. Meyer, J. Krause, S. Paabo, R.E. Green, R.K. Wayne

2013 Complete Mitochondrial Genomes of Ancient Canids Suggest a European Origin of Domestic Dogs. *Science* 342(6160):871-874.

Thompson, Keith

2007 Bones and joints. In *Jubb, Kennedy, and Palmer's Pathology of Domestic Animals,* Vol.1, Fifth Edition. Edited by M. Grant Maxie, Edinburgh: Elsevier Saunders, pp. 2-180.

Tito, Raul Y., Samuel L. Belknap III, Kristin D. Sobolik, Robert C. Ingraham, Lauren M. Cleeland, and Cecil M. Lewis,

2011 Brief Communication: DNA from Early Holocene American Dog. *American Journal of Physical Anthropology* 145(4), 653–657.

United States Census Bureau

2016 Quick Facts: Alaska. Electronic Document, http://www.census.gov/quickfacts/table/PST045215/02, accessed May 10, 2016.

Unruh, David

2009 *Zooarchaeology at the Coffey Site (14PO1): Mid-Holocene Economy on the Prairie Plains*. MA thesis, Department of Anthropology, University of Kansas, Lawrence.

Vallee, Frank G, Derek G. Smith, and Joseph D. Cooper

1984 Contemporary Canadian Inuit. In *Arctic,* edited by David Damas, pp. 662-675. *Handbook of North American Indians,* Vol. 5, William C. Sturtevant, general editor, Smithsonian Institution, Washington D.C.

Vilà, C., J.E. Maldonado and R.K. Wayne

1999 Phylogenetic Relationships, Evolution, and Genetic Diversity of the Domestic Dog. *The Journal of Heredity* 90(1):71-77.

Vilà, Charles, Peter Savolainen, Jesús E. Maldonado, Isabel R. Amorim, John E. Rice, Rodney L. Honeycutt, Keith A. Crandall, Joakim Lundenberg, Robert K. Wayne

1997 Multiple and ancient origins of the domestic dog. *Science* 276(5319):1687-1689.

Wang, Guo-Dong, Weiwei Zhai, He-chuan Yang, Ruo-xi Fan, Xue Cao, Li Zhong, Lu Wang,Fei Liu, Hong Wu, Lu-guang Cheng, Andrei D. Poyarkov Jr., Shu-sheng Tang, Wen-ming Zhao, Yun Gao, Xue-mei Lv, David M. Irwin, Peter Savolainen, Chung-I Wu and Ya-ping Zhang

2013 The Genomics of Selection in Dogs and the Parallel Evolution between Dogs and Humans. *Nature Communications* 4:1860.

Wang, Guo-Dong, Weiwei Zhai, He-Chuan Yang, Lu Wang, Li Zhong, Yan-Hu Liu, Ruo-Xi Fan, Ting-Ting Yin, Chun-Ling Zhu, Andrei D Poyarkov, David M. Irwin, Marjo K. Hytönen, Hannes Lohi, Chung-I Wu, Peter Savolainen, Ya-Ping Zhang

2016 Out of southern East Asia: The Natural History of Domestic Dogs across the World. *Cell Research* 26:21-33.

Walker, Danny N.

1982 Early Holocene Vertebrate Fauna. In *The Agate Basin Site: A Record of the Paleoindian Occupation of the Northwestern High Plains*, edited by George C. Frison and Dennis J. Stanford, pp. 274-308. Academic Press, New York.

Walker, Danny N. and George C. Frison

1982 Studies on Amerindian Dogs, 3: Prehistoric Wolf/dog Hybrids from the Northwestern Plains. Journal of Archaeological Science 9(2):125-172.

Warren, Diane M.

2000 Paleopathology of Archaic dogs from the North American Southeast. *BAR International Series* 889:105-114.

2004 Skeletal Biology and Paleopathology of Domestic Dogs from Prehistoric Alabama, Illinoi, Kentucky and Tennessee, Volume I. PhD dissertation, Department of Anthropology, Indiana University, Bloomington.

Wayne, Robert K. and Carles Vilà

2001 Phylogeny and Origin of the Domestic Dog. In *The Genetics of the Dog,* edited by Anatoly Ruvinsky and Jeff Sampson, pp. 1-11. CABI, Wallingford,Oxfordshire.

Wayne, Robert K. and Brigett M. vonHoldt

2012 Evolutionary Genomics of Dog Domestication. *Mammalian Genome* 23(1-2):3-18.

Widga, Christopher C.

2006 Bison, Bogs and Big Bluestem: The Subsistence Ecology of Middle Holocene Hunter-Gatherers in the Eastern Great Plains. PhD dissertation, Department of Anthropology, University of Kansas, Lawrence.

Wilson, Gilbert

1924 *The Horse and the Dog in Hidatsa Culture*. Anthropological Papers of the American Museum of Natural History 15(2):125-331. New York.

Wright, Jayne A.

1982 A Study of Vertebral Osteophyte Formation in the Canine Spine. I. Spinal Survey. *Journal of Small Animal Practice* 23(11): 697-711.

Zeder, Melinda A.

2012 Pathways to Animal Domestication. In *Biodiversity in Agriculture: Domestication, Evolution and Sustainability,* edited by Paul Gepts, Thomas R. Famula, and Robert L. Bettinger, pp.227-259. Cambridge University Press, Cambridge.

Appendix 1: Dog Breeds Assessed

English Name	Other Names	Total	Size Group
Afghan Hound	Afghanischeer Windhund	1	large
Appenzeller Sennenhund	Appenzeller Sennenhund	2	medium
Australian Terrier	Australian Terrier	1	small
Austrian Black and Tan Hound	Österreichische Bracke (Brandl)	1	medium
Belgian Tervuren	Tervueren	1	medium
Bernese Mountain Dog	Berner Sennenhund	2	large
Border Terrier	Border Terrier	2	small
Borzoi	Russian Wolfhound	4	large
Boston Terrier	Boston Terrier	1	small
Boxer	Boxer	1	medium
Briard	Berger de Brie	1	medium
Bullmastiff	Bullmastiff	1	large
Cairn Terrier	Cairn Terrier	1	small
Cavalier king Charles Spaniel	King Charles Spaniel Cavalier	2	small
Chihuahua	Chihuahua	7	small
Dachshund	Dachshund	2	small

Deutsch Stichelhaar	Vorstenhund, Dt. Stichelhaar	1	medium
Eurasier	Eurasier	2	small
German Shepherd	German Shepherd	1	large
German Spaniel	Deutscher Wachtelhund	2	medium
Gordon Setter	Gordon Setter	1	large
Great Dane	Deutsche Dogge	1	large
Greater Swiss Mountain Dog	Grosser Schweizer Sennenhund	1	large
Greyhound	Greyhound	4	large
Havanese	Havaneser	1	small
Hovawart	Hovawart	3	medium
Irish Setter	Irish Setter	1	large
Irish Wolfhound	Irish Wolfhound	6	large
Italian Greyhound	Italian Greyhound	2	small
Leonberger	Leonberger	1	large
Mastiff	Mastiff	1	large
Miniature Pinscher	Zwergpinscher	1	small
New Foundland	New Foundland	2	large
Norwich Terrier	Norwich Terrier	2	small
Nova Scotia Duck Tolling Retriever	Nova Scotia Duck Tolling Retriever	1	medium
Old English Sheepdog	Bobtail	1	medium

Otterhound	Pure bred otterhound	1	large
Pembroke Welsh Corgi	Welsch Corgi Pembroke	1	medium
Perro de Presa Canario	Dogo Canario	1	large
Peruvian Inca Orchid (Peruvian Hairless Dog)	Peruanischer nackthund (Perro sin Pelo del Peru)	1	small
Pit bull	Pit bull	1	medium
Pug	Mops	1	small
Rhodesian Ridgeback	Rhodesian Ridgeback	3	medium
Scottish Deer Hound	Scottish Deer Hound	1	large
Scottish Terrier	Scottish Terrier	2	small
Siberian Husky	Siberian Husky	1	medium
Skye Terrier	Skye Terrier	1	medium
Slovensky Cuvac	Slovensky Tschuwatsch	2	medium
Spanish Bulldog	Alano Espanol	1	large
Springer Spaniel	Springer Spaniel	1	large
St. Bernard	St. Bernhardshund	12	large
Swiss Hound	Schwyzer Laufhund	1	medium
Tibetan mastiff	Tibetan mastiff	1	large
Toy poodle	Toy poodle	1	small
Unknown		19	unknown
Vizsla	Vizsla	1	medium

Welsh Springer Spaniel	English Springer Spaniel	1	medium
White Swiss Shepherd Dog	Berger Blanc Suisse	4	large
Xoloitzcuintli	Mexikanischer Nackthund (Xoloitzcuintle)	3	medium
Total		**125**	