Flexion and Standing Extension in the Articulations of Alpacas (*Lama pacos*) and Llamas (*Lama glama*)

by

Amy L. Walters

A PROJECT

submitted to

Oregon State University
University Honors College

in partial fulfillment of the requirements for the degree of

Honors Baccalaureate of Science in Exercise and Sports Science (Honors Scholar)

Presented April 10, 2015
Commencement June 2015
AN ABSTRACT OF THE THESIS OF

Amy L. Walters for the degree of Honors Baccalaureate of Science in Exercise and Sports Science presented on April 10, 2015. Title: Flexion and Standing Extension in the Articulations of Alpacas (Lama pacos) and Llamas (Lama glama).

Abstract approved:

Stacy Semevolos

Objective- To determine the average flexion and standing extension measurements for each limb articulation of alpacas and llamas and determine if there was any significant difference between the species’ measurements.

Animals- Alpacas (n=6) and llamas (n=6) of the Oregon State University teaching herd.

Methods- Each articulation was measured four times in standing extension and in maximal passive flexion. Measurements were taken by two individuals, taking two measurements of each articulation.

Results- Average measurements for the shoulder, elbow, carpus, metacarpophalangeal, hip, stifle, hock, and metatarsophalangeal articulations in maximal flexion and standing extension were obtained. Flexion measurements showed no significant difference between the two species. In standing extension, the elbow (p=0.0313) and the hock (p=0.0214) showed a significant difference between the alpaca and the llama measurements. The rest of the articulations were found to have no significant difference.

Conclusion- Except for when dealing with the elbow and the hock in extension, the angle of a limb articulation can be considered the same for alpacas and llamas in flexion and extension. This has important relevance for veterinary surgeons when assessing joint mobility, conformation, and appropriate angles for arthrodesis. Expansion upon this research by radiography or CT of joints would be beneficial.

Key Words: alpaca, articulation, camelid, carpus, elbow, extension, fetlock, flexion, hip, hock, llama, metacarpophalangeal, metatarsophalangeal, shoulder, stifle, tarsus.

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APPROVED:

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Stacy Semevolos, Mentor, representing Veterinary Medicine

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Kim Hannigan-Downs, Committee Member, representing Exercise and Sports Science

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Toni Doolen, Dean, University Honors College

I understand that my project will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my project to any reader upon request.

______________________________________________________________________________
Amy L. Walters, Author
ACKNOWLEDGEMENTS

I am immensely grateful for Dr. Semevolos allowing me to take on this project and for all of the extensive help that she has offered me throughout the entire process. Without her help this thesis would not have been possible. I would also like to give special thanks to those who organize and contribute to the Experience Scholarship Fund. You have provided me with a way to make all of my research possible. The support that was provided will never be forgotten. Thank you to Dr. Rose Baker for helping to gather the measurements and for being on my committee. I would also like to thank Kim Hannigan-Downs for being a part of my committee and for being a wonderful teacher. Also, I would like to thank Dr. Terri Clark for the pictures she allowed me to use. Lastly, I would like to thank my parents and my fiancé Jamie for always being there for me throughout this process, I could not have done it without your support.
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**Defined words**

**Arthrodesis:** a surgery that results in joint fusion.

**Articulation:** a joint, composed of two or more bones, where movement occurs.

**Cush:** the recumbent position of a camelid, limbs under body.

**Extension:** when an articulation is moved into a straight (extended) position and the two adjacent bones are moved farther apart.

**Fetlock:** the camelid joint that can either refer to the metacarpophalangeal joint or the metatarsophalangeal joint. These two joints are very similar and are made up of the metacarpus or the metatarsus, respectively, four sigmoid bones, and two phalangeal bones.

**Flexion:** when an articulation is moved into a bent (flexed) position and the two adjacent bones are moved closer together.

**Goniometer:** a tool that is used to measure the angle between two bones of a joint.

**Hock:** the camelid joint that is formed between the tibia and the metatarsus and also includes the talus, calcaneus, central tarsal bone, first tarsal bone, second and third tarsal bone, and the fourth tarsal bone.

**Stifle:** the camelid joint that is formed between the femur and tibia. It is similar to that of the human knee.

**T test:** A statistical test that is run to compare the means of two samples and measures the amount of difference between them, provides the p value.
CHAPTER 1

Introduction

1.1 Introduction

Alpacas (*Lama pacos*) and llamas (*Lama glama*) are both part of the same biological family that is referred to as the Camelidae family. The origins of this family can be traced back to North America (Marzuola, 2003). It is believed that during the evolution of these animals, they split into two different groups with one migrating over to Asia and the other migrating down to South America (Marzuola, 2003). As this happened, in combination with thousands of years, the group that migrated to Asia evolved into camels and the group in South America evolved into alpacas and llamas, or Andean camelids as they are collectively called (Marzuola, 2003; & Campero, 2005).

The countries that are considered to be the native lands of alpacas and llamas are Argentina, Bolivia, Chile, and Peru (Campero, 2005). They have adapted to live at an elevation that ranges from 2,800 meters to 5,000 meters by having higher levels of red blood cells than many other mammals (Campero, 2005). This adaptation allows for these animals to carry more oxygen in their bloodstream and gives their blood a vibrant red appearance (Campero, 2005).

With the advancement of mankind, it is believed that the Incas were the first people to domesticate these two species (Marzuola, 2003). As these animals were domesticated, it resulted in the Andean camelids becoming four distinct groups with two being wild, the guanaco and vicuna, and two being domesticated, the alpaca and llama (Campero, 2005). During the era of the Incan civilization, alpacas were used only for their thick fiber (Campero, 2005). Since llamas are typically much stronger than alpacas,
the Incas used them primarily as pack animals and for their meat (Campero, 2005). The
use of llama fiber was a secondary commodity (Campero, 2005).

It is only within recent history that alpacas and llamas have grown in popularity
within North America and across the globe (Newman & Anderson, 2009). The use of
alpacas and llamas today is largely similar to what it was during the time of the Inca’s.
The alpaca market has expanded and now has a large emphasis on showing and breeding
both focusing on fiber quality (Semevolos, et al., 2008). Llamas have become quite
valuable as guard animals among other livestock, along with having a small market in
showing and breeding (Semevolos et al., 2008). The growth in the market surrounding
alpacas and llamas has increased the need for veterinarian knowledge regarding these two
species. It has become quite common for large animal veterinarians to treat camelids on a
regular basis (Newman & Anderson, 2009).

As much as the veterinarian knowledge of these two Andean camelids has
expanded, the average standing angles (referred to in this study as extension) and the
average flexion angles for these two species’ limb articulations has not been investigated.
Extension is when an articulation moves into its most straight position where the adjacent
bones are moving away from each other. Flexion is the opposite, and occurs when an
articulation is bent and the two adjacent bones are brought closer together. Currently it is
unknown whether or not these values are different between alpacas and llamas. Knowing
the average extension and flexion measurements for each articulation for both species
would benefit the veterinarian community in numerous ways.

Acquiring this information would be valuable when treating the many orthopedic
injuries that camelids can acquire. Camelids are known for responding quite well to
orthopedic surgeries due to their relatively low body weight, their ability to ambulate on only three limbs if one is immobilized, and their high tolerance for long durations of being recumbent which is often required for full recovery (Newman & Anderson, 2009). These traits, along with the fact that alpacas and llamas are valuable livestock, are reasons why owners of these animals commonly opt for orthopedic surgeries rather than having to put their camelids down. Orthopedic surgeries for camelids mainly consist of fracture fixation repairs and joint fusion surgeries (arthrodesis).

Fractures can either be repaired by external or internal fixation (Newman & Anderson, 2009). External fixation typically involves pins placed across the bone which are then stabilized by some form of a cast (Newman & Anderson, 2009). Internal fixation, as the name suggests, requires surgical reduction of the fracture followed by plating or other implants to stabilize the fracture (Newman & Anderson, 2009). In both of these instances, knowing the articulations average extension and flexion angles would aid in the surgical repair process.

Arthrodesis is used to manage limb deformities causing lameness, instability, and osteoarthritis (Woodford, D’Altero, & Owen, 2007). In some severe cases, angular limb deformity may lead to degenerative osteoarthritis (Fahlman, et al., 2014). In these cases, arthrodesis can be used to restore function to the camelid’s limb by fusing the bones of the articulation together. When using this technique, motion at that joint is lost, making it imperative that the articulation is fused in the position that is most optimal for the camelid. Knowing the average standing joint angle for each articulation would allow for the fused position to better mimic the camelid’s natural position.
Due to the limited research conducted on arthrodesis of camelids, useful information can be gathered from research that has been performed on dogs. It has been shown that when dogs undergo arthrodesis and their articulations are fixed into positions that are either too far flexed or too far extended past their natural angles, they have difficulties weight bearing (Dyce, 1996). Articulations fixed in overly flexed positions, result in limb length disparity between the two sides of the dog’s body which will directly impede weight bearing (Dyce, 1996). Conversely, an articulation fixed into overly extended positions hinders circumduction of the limb, indirectly affecting their ability to properly walk (Dyce, 1996). Average extension and flexion measurements at each articulation are already known in dogs (Jaegger, Marcellin-Little, & Levine, 2002; & Thomas, et al., 2006). These measurements provide essential surgical arthrodesis angle approximations, and the end product is typically successful with only mild lameness present (Fitzpatrick, et al., 2012). Because these measurements are lacking in camelids, it is imperative that this gap in knowledge be filled.

In addition to aiding fracture repair and arthrodesis surgical planning, knowing the articulations’ average extension and flexion measurements will also help veterinarians assess osteoarthritis in camelids and their comparative ranges of motion.

1.2 Purpose

Therefore, the main purpose of this research study was to determine the average standing extension and maximum flexion angles of all limb articulations in healthy alpacas and llamas. The second goal was to determine if there were any differences between alpacas and llamas in the average standing extension and flexion angles. In this
study we investigated the shoulder, elbow, carpus, fetlock [metacarpophalangeal (MCP) and metatarsophalangeal (MTP)], hip (coxofemoral), stifle (femorotibial), and hock (tarsus) articulations. We hypothesized that there would be no significant difference between the average angle measurements of alpacas versus llamas for any given articulation in either extension or flexion.
CHAPTER 2

Methods

2.1 Subjects

In total, measurements were collected from twenty-four different animals through a convenience sample. However, many were incomplete sets and were not used in the final data analysis. For a camelid to have a complete set they needed to have four measurements from each articulation in the standing position and four measurements for each articulation in the maximally flexed position.

The complete data sets used in this study included six alpacas and six llamas that were healthy, with no obvious gait abnormalities. All of the animals were a part of the Oregon State University veterinary teaching herd. Alpacas and llamas can have a lifespan of twenty to twenty-five years (Wolff, 2007). Measurements were obtained from animals ranging from two years old to twelve years old with an average age of 6.17 years old ± 3.43 (SD). When looking solely at the alpacas (Table 1), their ages ranged from five years old to twelve years old with an average of 8.17 years old ± 2.93 (SD). The llamas’ ages (Table 2) ranged from two years old to nine years old with an average age of 4.17 years old ± 2.79 (SD).

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<thead>
<tr>
<th>Identification</th>
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<td>8</td>
</tr>
<tr>
<td>A6</td>
<td>Female</td>
<td>8</td>
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</tbody>
</table>

Table 1. Alpaca subjects identification, gender, and age.
2.2 Gathering Measurements

Once the subjects were identified from the herd, they were brought in to the Veterinary Teaching Hospital at Oregon State University. Taking the measurements required a universal goniometer and two individuals. A goniometer is a standard tool that is used to take articulation angle measurements across many species.

For each animal, measurements always began with extension on the left front limb and then moved to the left hind limb. The measurements for each articulation were taken two times by two separate individuals resulting in four measurements per articulation. This process was then repeated on the right side of the body.

Once all of the standing angles were gathered, the articulations were moved into maximum passive flexion and the measurements were taken. The order in which the measurements were taken remained the same with duplicate measurements taken by two separate individuals.

Table 2. Llama subjects identification, gender, and age.

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<td>2</td>
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<tr>
<td>L6</td>
<td>Female</td>
<td>2</td>
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</table>
2.3 Medication

Most of the camelids tolerated the measurement procedure without need for sedation. However, there were two cases in which sedation was necessary to allow the measurements to be taken. The first was with L3 (Table 2). He was administered a total of 30mg of xylazine intramuscularly to allow data collection. The second was A4 (Table 1), which required 5mg of butorphanol intramuscularly.

2.4 Statistical Analysis

Two sample T tests were performed to evaluate comparisons (p≤0.05) between the average standing extension and flexion angles between alpacas and llamas. Once it was established that there was no significant difference between the left and right averages for each articulation, these averages were combined for each species.
3.1 Introduction

The limb articulations measured were the shoulder, elbow, carpus, and fetlock joints of the front limbs and the hip, stifle, hock, and fetlock joints of the hind limbs. A total of sixteen individual articulations were measured on each camelid since there were four articulations measured on each limb. Figure 1 depicts the overall skeletal bone structure of camelids.

Figure 1. Llama skeleton. (Courtesy of Dr. Terri Clark.)
(A) Shoulder (B) Elbow (C) Carpus (D) Fetlock (E) Hip (F) Stifle (G) Hock (H) Fetlock.
3.2 Front Leg Articulations

3.2a Shoulder Articulation

Similar to many other mammals, the camelid shoulder articulation is made up of the scapula and the humerus (Fowler, 2010, p. 315). When measuring this articulation, the axis of the goniometer was placed over the top of the lateral aspect of the shoulder. Then the arms of the goniometer were positioned with one arm along the scapular spine towards the cervical vertebrae and the other arm centered along the humerus toward the elbow.

3.2b Elbow Articulation

The elbow articulation of a camelid is composed of the humerus and the radius (Fowler, 2010, p. 316). For measuring the elbow articulation, the axis of the goniometer was placed on the lateral aspect of the elbow joint and the arms of the goniometer were positioned with one centered along the humerus toward the shoulder and the other centered along the radius toward the carpus.

3.2c Carpus Articulation

A camelid carpus articulation is made up of nine different bones (Fowler, 2010, p. 317). These bones are: the radius, accessory carpal bone, radial carpal bone, intermediate carpal bone, ulnar carpal bone, second carpal bone, third carpal bone, fourth carpal bone, and the metacarpus (Fowler, 2010, p.317). Figures 2 and 3 show how all of these bones come together in a dorsal and lateral view respectively. The second carpal bone is not visible in either of the figures below. It is best seen when the articulation is examined from a medial
perspective. These nine bones come together to form three individual articulations: the radiocarpal joint, the middle carpal joint, and the carpometacarpal joint. Both the radiocarpal and the middle carpal joints are high motion joints, while the carpometacarpal joint is a low motion joint. When measurements of this articulation were taken, the carpus was treated as one functional articulation rather than being broken down into the three separate articulations. Therefore, the measurements were taken midway between the radiocarpal joint and the middle carpal joint. To measure this articulation, the axis of the goniometer was placed over the joint, which was easily distinguishable with all of the bones present. The arms of the goniometer were then positioned so that one was centered along the lateral radius toward the elbow and the other centered along the metacarpus toward the fetlock.

Figure 3. Llama carpus articulation, dorsal view. (Courtesy of Dr. Terri Clark.)
(A) Radius (B) Ulnar carpal bone (C) Intermediate carpal bone (D) Radiocarpal bone (E) Fourth carpal bone (F) Third carpal bone (G) Metacarpus (H) Accessory carpal bone.

Figure 2. Llama carpus articulation, lateral view. (Courtesy of Dr. Terri Clark.)
3.2d Metacarpophalangeal Articulation

The metacarpophalangeal articulation is made up of the metacarpus (fused third and fourth metacarpal bones), four sesamoid bones, and two phalangeal bones (Fowler, 2010, p. 318). Figure 4 shows how all of these bones come together. The image has been taken in the lateral view. To measure this articulation, the axis of the goniometer was positioned over the lateral aspect of the fetlock joint, with one arm of the goniometer centered along the lateral metacarpus toward the carpus and the other along the first phalanx toward the inter-phalangeal articulations. For these measurements, a small goniometer was used so that the arms would not be inhibited by the ground.

Figure 4. Llama fetlock articulation, lateral view. (Courtesy of Dr. Terri Clark.)
(A) Metacarpus (B) Sesamoid bone (C) Phalangeal bone (first phalanx).
3.3 Hind Leg Articulations

3.3a Hip Articulation

A camelid hip (coxofemoral) joint is composed of the acetabulum of the pelvis and the femur (Fowler, 2010, p. 312). To gather measurements for this articulation, the axis of the goniometer was placed over the center of the joint with one arm centered along the lateral aspect of the femur toward the stifle and the other along the ilium toward the lumbar vertebrae.

3.3b Stifle Articulation

The camelid stifle is made up of three bones: the femur, patella, and tibia (Fowler, 2010, p.320). These measurements were taken with the axis of the goniometer laterally centered over the femorotibial articulation with one arm centered along the femur toward the hip and the other centered along the tibia toward the hock.

3.3c Hock Articulation

The hock is also frequently called the tarsus. The bones that compose this articulation are the tibia, talus, calcaneus, central tarsal bone, first tarsal bone, fused second and third tarsal bone, fourth tarsal bone, and the metatarsus (Fowler, 2010, p. 321). Figures 5 and 6 show how all of these bones come together to form this articulation in a medial and dorsal view respectively. The first tarsal bone is not visible in either of the figures below. It is best seen when the articulation is examined from a lateral perspective. These bones come together and form four separate articulations: the tibiotarsal, proximal intertarsal, distal intertarsal, and
the tarsometatarsal articulations. Within these four joints, the tibiotarsal and the proximal intertarsal articulations are considered to be high motion joints. Of these two, the tibiotarsal has the most available motion. The other two joints, the distal intertarsal and the tarsometatarsal, have little motion available. When the measurements for this articulation were taken, the hock was considered to be one functional articulation. The axis of the goniometer was placed halfway between the tibiotarsal articulation and the proximal intertarsal articulation, with one arm of the goniometer centered on the tibia toward the stifle and the other arm centered on the metatarsus toward the metatarsophalangeal articulation.

Figure 6. Llama hock articulation, medial view. (Courtesy of Dr. Terri Clark.)

Figure 5. Llama hock articulation, dorsal view. (Courtesy of Dr. Terri Clark.)

(A) Tibia (B) Tuber calcis (C) Talus (D) Calcaneus (E) Central tarsal bone (F) Second and third tarsal bones (G) Fourth tarsal bone (H) Metatarsus
3.3d Metatarsophalangeal Articulation

The metatarsophalangeal articulation is structurally the same as the metacarpophalangeal articulation and Figure 4 can be used to illustrate both of them. They are also both referred to as the fetlock. The bones in the MTP articulation are the metatarsus, four sesamoid bones, and two phalangeal bones (Fowler, 2010, p.318). To measure this articulation, the axis of the goniometer was placed directly over where the angle in the fetlock naturally occurs with one arm along the metatarsus toward the hock and the other arm along the first phalanx toward the inter-phalangeal articulations. A small goniometer was used to take the measurements so that the arms would not be impeded by the ground.
CHAPTER 4

Results

4.1 Introduction

First we determined the average measurements for both the left and right articulations in extension and flexion for each camelid measured. We then ran a two sample T test for each articulation comparing the left and right averages and found no significant difference between the left and right sides for each joint. The left and right sides were then averaged together for each joint within each animal and the results displayed in Tables 3, 4, 5, and 6.

4.2 Alpacas

<table>
<thead>
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<th>Stifle</th>
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<td>117.500</td>
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Table 3. Average alpaca standing extension by articulation.
### Table 4. Average alpaca flexion by articulation.

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<thead>
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<th>Shoulder</th>
<th>Elbow</th>
<th>Carpus</th>
<th>MCP</th>
<th>Hip</th>
<th>Stifle</th>
<th>Hock</th>
<th>MTP</th>
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### 4.3 Llamas

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<th>MCP</th>
<th>Hip</th>
<th>Stifle</th>
<th>Hock</th>
<th>MTP</th>
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<td>125.125</td>
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<td>124.125</td>
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<td>121.750</td>
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<td>L4</td>
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<td>117.750</td>
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<td>118.750</td>
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<td>157.625</td>
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<td>116.750</td>
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</tr>
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<td>93.146</td>
<td>120.708</td>
<td>149.417</td>
<td>139.979</td>
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</table>

Table 5. Average llama standing extension by articulation.
4.4 Compare and Contrast

No significant difference was found in the average extension measurements between alpacas and llamas in the shoulder (p=1.0), carpus (p=0.6951), metacarpophalangeal (p=0.9182), hip (p=0.5267), stifle (p=0.1181), and the metatarsophalangeal (p=0.3149) articulations. There was a significant difference in the average extension measurements of the elbow (p=0.0313) and the hock (p=0.0214) between alpacas and llamas. It was found that for both of these articulations that llamas had a larger average standing extension angle than alpacas. For the elbow articulation, llamas had an average of 121.833 degrees of extension, while alpacas had an average of 117.917 degrees. Llamas had an average of 149.417 degrees of extension in the hock and alpacas had an average of 139.646 degrees. Figures 7 and 8 show the average extension angle for these two articulations and the variation that was found to exist. In Figure 7, it is evident that the elbow articulation of llamas has a larger amount of variation from the mean.

Table 6. Average llama flexion by articulation.
(depicted by the size of the standard error bar) than that of alpacas. Subsequently, Figure 8 shows that the average extension angle of the hock of llamas has less variation than alpacas.

Figure 7. Average elbow standing extension in alpacas and llamas with standard error bars.

Figure 8. Average hock standing extension in alpacas and llamas with standard error bars.
There was no significant difference in the average flexion measurements between alpacas and llamas for all of the articulations measured. The p values for the articulations were: shoulder (p=0.7336), elbow (p=0.4604), carpus (p=0.6278), MCP (p=0.9979), hip (p=0.1786), stifle (p=0.8570), hock (p=0.7577), and the MTP (p=0.1355). Our study showed no significant difference between the MCP and MTP articulations in either extension or flexion for both alpacas (extension: p=0.4186, flexion: p=0.7813) and llamas (extension: p= 0.6086, flexion: p=0.3752).
CHAPTER 5
Discussion

5.1 Importance

Our hypothesis was primarily supported by the data. While there was no significant difference between the average maximum flexion measurements of alpacas and llamas, there were two articulations that showed a significant difference in their standing extension measurements; the elbow and the hock. Llamas were found to have greater standing extension than alpacas in these two articulations. All other articulations were discovered to have no significant difference in their standing extension measurements between alpacas and llamas.

This data provides veterinarians with knowledge that will help them as they care for the general health of camelids. Since this is the first research study of this nature that we can determine, we have to compare the importance of our findings with the findings in other studies established in dogs and humans.

5.2 Compared to Other Species

When comparing the average extension and flexion angles of alpacas and llamas found in this study to that of the average angles of dogs, two studies were referenced. The first study gathered measurements on sixteen Labrador Retrievers and the second on twelve German Shepherds (Jaegger, et al., 2002; & Thomas, et al., 2006). Neither of these studies took measurements on the metacarpophalangeal or metatarsophalangeal articulations, so there will be no comparison of these articulations between dogs and the camelids of this study.
In all six articulations being compared (shoulder, elbow, carpus, hip, stifle, and tarsus) it was seen in both studies that dogs have greater amounts of extension than both alpacas and llamas (Tables 7 and 8) (Jaegger, et al., 2002; & Thomas, et al., 2006). The reason for this can be accounted for due to the structural and functional differences between the species. The comparisons made in regard to the average degree of flexion are not as straightforward. For alpacas and llamas, when their average shoulder, hip, and stifle flexion angles are compared with those of dogs, it can be seen that alpacas and llamas have greater amounts of flexion (Jaegger, et al., 2002; & Thomas, et al., 2006). However, in the carpus and tarsus articulations, both the alpaca’s and llama’s average flexion angles are less than that of dogs (Jaegger, et al., 2002; & Thomas, et al., 2006). The elbow articulation was found to have inconclusive results when compared with these two studies. Alpacas were found to have less flexion in the elbow articulation when compared to Labrador Retrievers, while llamas were found to have an equal average amount of flexion (Jaegger, et al. 2002). Both the alpacas and llamas had a greater average degree of flexion compared to German Shepherds (Jaegger, et al., 2002; & Thomas, et al., 2006). A possible explanation for this is that the studies used two different breeds of dogs.

The average extension and flexion measurements of humans have been widely studied. When articulation angles are taken on humans, it is all done in reference to the anatomical position. In this position, all joint angles are deemed to be zero degrees. When someone is in the anatomical position they are standing erect with their feet pointing forward and slightly apart, their arms are at their sides with palms facing forward and they are looking straight ahead. It is flexion or hyperextension away from this set position.
that is then measured. Extension is only the motion of the joint returning from a flexed position to its anatomical position, any motion past zero is considered hyperextension.

There is no set zero reference position, such as that of humans, when measuring the articulation angles of camelids, although the standing position may be considered the equivalent. It is for this reason that when comparing the measurements of alpacas and llamas to humans, alpacas and llamas should typically have higher angles of extension (American Academy of Orthopedic Surgeons, 1965). For humans the MCP and the MTP articulations of the first digit of the hands and feet are able to obtain greater amounts of motion compared to the other four digits (American Academy of Orthopedic Surgeons, 1965). For the purpose of this study only the angle measurements from digits two through five were used for comparisons as the first digit joints do not have an equal articulation of comparison in quadrupeds.

Comparisons also show that in all articulations except for the tarsus and the MTP, humans have a higher degree of flexion than camelids (American Academy of Orthopedic Surgeons., 1965). In humans, the tarsus has an average of 20 degrees of flexion (plantar-flexion) while alpacas have 27 degrees and llamas 28 degrees (American Academy of Orthopedic Surgeons, 1965). This may be because the tarsus articulation of humans is in contact with the ground, while the camelids’ is not, and therefore has a smaller degree of flexion to increase stability. For the MTP articulation, humans on average have 40 degrees of flexion while alpacas and llamas have 84 degrees and 75 degrees respectively. This difference may be accounted for by the different styles of gait between camelids and humans (American Academy of Orthopedic Surgeons, 1965). An explanation for humans having greater amounts of flexion in most of their articulations
versus camelids could be explained by the fact that humans are bipeds, while camelids are quadrupeds. Having a more limited degree of flexion, compared to humans, would suggest that camelids’ articulations are more stable than humans’.

<table>
<thead>
<tr>
<th>Species</th>
<th>Shoulder</th>
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<th>Carpus</th>
<th>MCP</th>
<th>Hip</th>
<th>Stifle/Knee</th>
<th>Tarsus</th>
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<tr>
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<td>115</td>
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<td>153</td>
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<td>0</td>
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Table 7. Comparison of articulation extension averages across species.
*Human measurements were taken from a set zero position, anatomical position, while the other species were not. (American Academy of Orthopedic Surgeons, 1965; Jaegger, et al., 2002; & Thomas, et al., 2006).

<table>
<thead>
<tr>
<th>Species</th>
<th>Shoulder</th>
<th>Elbow</th>
<th>Carpus</th>
<th>MCP</th>
<th>Hip</th>
<th>Stifle/Knee</th>
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<td>82</td>
<td>62</td>
<td>48</td>
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<td>84</td>
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<tr>
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</tbody>
</table>

Table 8. Comparison of articulation flexion averages across species.
*Human measurements were taken from a set zero position, anatomical position, while the other species were not. (American Academy of Orthopedic Surgeons, 1965; Jaegger, et al., 2002; & Thomas, et al., 2006).

### 5.3 Goniometry

One of the main goals of this research study was to establish a set of average angles for each limb articulation in extension and flexion. Another goal was to determine
whether or not there was a significant difference between these average measurements when compared between alpacas and llamas. To gather these measurements we used universal plastic goniometers with one degree increments. There have been many studies to test the reliability of the measurements taken by goniometers. When the reliability of goniometers is being studied, both intertester reliability and intratester reliability are examined. Intertester reliability is the amount of variation that exists when there are two or more individuals taking measurements (Ekstrand, et al., 1982). In contrast, intratester reliability is the amount of variation that occurs in measurements that are all taken by the same individual (Ekstrand, et al., 1982). Across humans, dogs, and horses it has been found that intratester reliability is higher than intertester reliability (Ekstrand, et al., 1982; Liljebrink, & Bergh, 2010; & Jaegger, et al., 2002).

Intertester and intratester reliability in camelids is one area for further research. To help advance this research, we ran a Pearson’s correlation test on our data to determine the linear correlation that existed between the measurements taken by the two individuals who collected data (Table 9). The fetlock articulations, the metacarpophalangeal (extension: 0.9457, flexion: 0.9233) and the metatarsophalangeal (extension: 0.9117, flexion: 0.9149), have the highest amount of correlation in both standing extension and flexion. These articulations are covered in minimal amounts of fiber and their natural joint angles are quite obvious. The high correlation values for the MCP and the MTP in standing extension and flexion attest to the accuracy of the measurements taken at these articulations.

The lowest correlation values were found to exist between the measurements taken at the shoulder in extension (0.1255), the carpus in flexion (0.3156), the hip in both
extension and flexion (extension: 0.5633, flexion: 0.5512), and the tarsus in flexion (0.4331). The low correlation values of the carpus and tarsus in flexion may be explained by the complexity of their structure. The carpus is composed of nine bones that form three different articulations and the tarsus has eight bones that comprise four different articulations. For measurements taken at the shoulder and hip articulations, the bony landmarks have to be identified and palpated through the thick fiber present on these areas of the camelids. This fiber is most likely the cause for the lower correlation values at these articulations. As shearing is not always an option, to improve these correlation values for future research, radiographs could be used.

<table>
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<th>Flexion</th>
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<td>0.4331</td>
</tr>
<tr>
<td>MTP</td>
<td>0.9117</td>
<td>0.9149</td>
</tr>
</tbody>
</table>

Table 9. Correlation values between the two researcher’s averages for each articulation in standing extension and flexion.

In most cases using a radiograph to obtain the articulation measurements is considered the gold standard (Liljebrink, et al., 2010). However in a study conducted with the purpose of comparing goniometer and radiograph measurements of the articulations of dogs, no significant difference was found between these two methods (Jaegger, et al., 2002). It has also been shown through two different studies that
goniometers are reliable for measuring the passive motion of dogs (Jaegger, et al., 2002; & Thomas, et al., 2006).

Goniometers are also used in the field of physical therapy with humans and animals to assess range of motion after injuries and to track their improvement throughout therapy. This process typically involves multiple measurements being taken in different planes to assess the patient’s overall function. As mentioned earlier, all human measurements are taken in reference to the anatomic position. By assessing an individual’s range of motion, the physical therapist can then determine what areas need improvement based on any limitations that are found. A few techniques to increase range of motion are active and passive stretching, joint mobilizations, and heating techniques. When someone has compromised movement in one or more planes, this affects their entire life. Among other things, it can change the way they walk, carry items, or do tasks of daily living. While these changes may seem minor, overtime they can have a large effect on individuals through the secondary injuries that they cause. A changed gait pattern as a result of reduced hip flexion and extension can cause knee and/or back pain. Examining the importance of having full range of motion in humans gives insight into the extent to which the average articulation angles found in this study for alpacas and llamas will benefit veterinarians through enhancing the overall health assessments and treatments of camelids.

5.4 Limitations

With this study being the first of its kind, there are some limitations that are important to consider. Primarily, our sample of camelids was a convenience sample. The
camelids measured were from the Oregon State University teaching herd. Those included were only those that were deemed to be young and healthy in relation to the average lifespan of their species. Secondly, because this study was a convenience sample, the number of camelids within the study is relatively small. It will take more studies to confirm and refine the data found in this study before an overall generalization can be made. A third limitation to our study is that we were not able to take radiographs of the articulations or have access to previously taken radiographs. Taking radiographs in future studies would be helpful for comparing with the goniometric measurements that were taken.

This study offers significant value as the starting block for future studies to come. The limitations mentioned are areas for further research.
CHAPTER 6

Conclusion

In this study a significant difference between the average standing extension measurements of the elbow (p=0.0313) and hock (p=0.0214) articulations was found between alpacas and llamas. All other articulations showed no significant difference in the average standing extension measurements between alpacas and llamas. It was also found that there was no significant difference between the average flexion measurements of alpacas and llamas in all limb articulations.

With the growing popularity of camelids these results will prove to be beneficial to the veterinarian community in various ways. Our findings provide standard standing extension and flexion angles of the limb articulations of camelids. Knowing these values and the differences that exist between alpacas and llamas will greatly improve the accuracy of arthrodesis surgeries. The ability to obtain the most optimal position for the articulation to be fused in will be easier with these findings as a guide.

This study offers a basis for continued and expanded research. While taking angle measurements is a complex process, these universal goniometers have been shown to be reliable in gathering articulation angle measurements in humans, dogs, and horses (Ekstrand, et al., 1982; Liljebrink, & Bergh, 2010; Jaegger, et al., 2002; & Thomas et al., 2006). Research into the variability that exists in obtaining angle measurements through the use of a universal goniometer and the use of radiography in alpacas and llamas would serve to better validate these findings and direct future studies. Secondarily, it may prove beneficial to study the differences that may exist between the two genders of camelids and their average articulation angles in extension and flexion.
References


