Femorotibial joint angles of pigs

The influence of stride length and age

N.C. Spitzers
3516253
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Supervisor:
Dr. C.F. Wolschrijn

Summary

The aim of this study was to determine whether there was a significant difference between the sagittal joint angles and the passive range of motion of the femorotibial joint of pigs with a short stride length compared to pigs with a long stride length. Also we wanted to determine whether there was such a difference between the joint angles for abduction and adduction and the passive range of motion around the craniocaudal axis of young pigs and older pigs. For this study, twelve pigs ranging from ten to twelve weeks of age were selected.

To determine the stride length of these pigs, the animals were recorded while walking through a test hall. From these tapes, four frames were taken from each pig in order to calculate the average stride length of each pig. Also, radiographs were made with the femorotibial joint consecutively in neutral position, maximal extension, maximal flexion, maximal abduction and maximal adduction. Based on these radiographs, the maximum joint angles per animal were determined.

Based on the stride length measured, the pigs were split into groups based on their stride length (either short or long). The total group of twelve pigs was also divided based on their age, either in a group ranging in age from ten to eleven weeks, or a group ranging from eleven to twelve weeks of age.

Regarding the sagittal joint angles and range of motion, there were only numeric differences observed between the group with a short stride length and the group with a long stride length; however the averages of these did not differ significantly. The differences between the joint angles in the frontal plane and the corresponding range of motion of pigs from ten to eleven weeks of age and pigs of eleven to twelve weeks of age also did not differ significantly. The conclusion of this study is that there is no significant difference between the joint angles and range of motion of the femorotibial joint between pigs with a short stride length and pigs with a long stride length, nor between piglets from ten to eleven weeks of age and older piglets.

Contents

Introduction

Wild boars live in deciduous or mixed forests, where they have a large habitat. This habitat is so extensive, because they need room for rooting, mud bathing, searching food and a place to sleep (Stolba, Wood-Gush 1989, Graves 1984). The soil of their territory neither consists of loose sand nor rock, but it has rather the structure of peat: coarse and spongy. The body and the claws of the wild boar are adapted to its environment and soil.
The habitat of pigs nowadays, when kept for production, is very different from the environment just described for the wild boar. Our pigs are usually held without the possibility of rooting or taking a mud bath, and the surface of the stable floor for weaned piglets and fattening pigs consists of concrete with a partially slatted floor. This surface is much harder than the soil in their natural habitat, which might cause various problems and disorders in these piglets.
One of the problems that is caused by the current environment of production pigs is tail biting. Wild boars have the natural tendency to root and chew on objects while they are foraging. In a stable with a concrete floor rooting is impossible, so the pigs will chew on other objects than leafs while foraging, namely the tails of their stable mates. (Sonoda, Fels et al. 2013) This tail biting causes welfare problems for the pigs and a reduction of income for the farmer.

Slipping and joint angles

Another problem that is caused by this environment is that the pigs show slipping in the stable (von Wachenfelt, Nilsson et al. 2010), something that rarely occurs when they are in their natural habitat. After a period of time, the floor becomes more slippery because the faeces from the slatted floor are spread on the concrete floor via the legs and claws of the piglets. Due to this dirty floor, the friction force of the soil is reduced, whereby the frequency of slipping increases (Thorup, Tøgersen et al. 2007, von Wachenfelt, Pinzke et al. 2009). To prevent slipping, the muscle strength just before the swing phase (during push-off) must be less than or equal to the friction force of the soil. This adjustment in the muscle strength causes a shorter stride length, thereby reducing the frequency of slipping (von Wachenfelt, Pinzke et al. 2009).

The stride length can thus be reduced physiologically, as a preventive measure against slipping. However, the stride length can also be shortened pathologically in case of rupture of the cranial cruciate ligament or degenerative joint disease (Sanchez-Bustinduy, de Medeiros et al. 2010, Gyory, Chao et al. 1976). In these conditions a significant difference between the joint angles of the femorotibial joint of affected animals and healthy animals has been reported (DeCamp, Riggs et al. 1996, Lascelles, Dong et al. 2012).

Stability of the femorotibial joint and the influence of age

Different structures, including the cruciate ligaments, the menisci and the collateral ligaments, provide stability of the femorotibial joint (see figure 1). These structures not only give stability of the joint, but also distribute the forces more evenly across the joint during movement/locomotion (Jerram, Walker 2003). The collateral ligaments mainly restrain the joint to the craniocaudal axis, preventing ab- and adduction during loading (Paterno, Hewett 2008, Brantigan, Voshell 1943). Additionally, the collateral ligaments also help to restrict endo- and exorotation of the femorotibial joint, but most of this restriction is achieved by the cruciate ligaments (Brantigan, Voshell 1943, Jerram, Walker 2003).

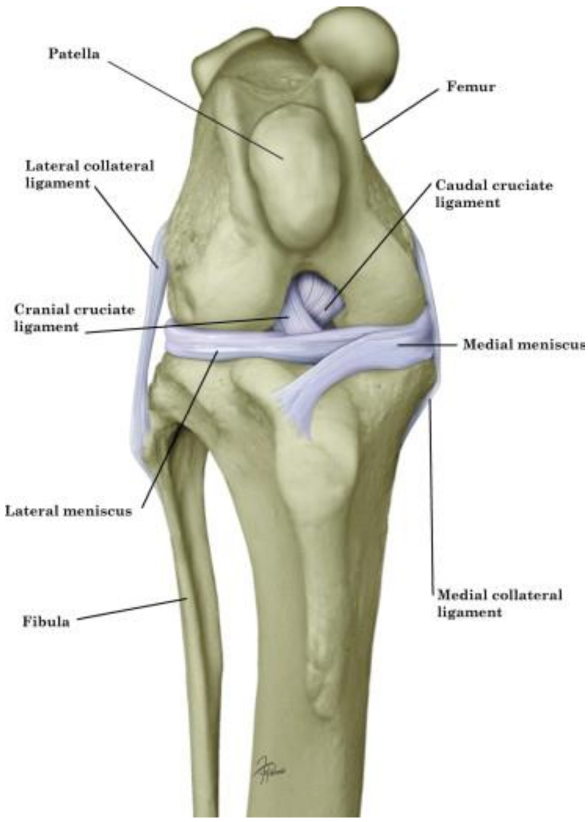

Figure 1. Representation of the stifle joint, including the structures that provide stability to the joint (Canapp Jr. 2007).

Stability provided by ligaments is dependent on three properties: the place of attachment, the length of the ligament at maximum tension and the elasticity.
An elevation of the joint line of the femorotibial joint causes a change in the flexion axis of the knee concerning the places of attachment of the collateral ligaments to the femur. Consequently, the length of the collateral ligaments is altered at different angles of flexion. Because of this alteration, the varus-valgus stability of the joint during walking is compromised at some points in the walking cycle (König, Matziolis et al. 2011).
The stability of the femorotibial joint can be affected by diseases like osteoarthritis. The collateral ligaments can get relatively too long when the femorotibial surfaces come closer to each other as an effect of the degeneration of the menisci and the articular cartilage. Due to this, the knee is more instable and will go easier into a varus or valgus alignment, exacerbating the degeneration and causing a vicious circle (Ramsey, Briem et al. 2007). The femorotibial joint can bear this instability by reflexively activate muscles' around the joint (Lewek, Ramsey et al. 2005). For example, mechanical stimulation of the medial collateral ligament of the cat's femorotibial joint leads to the contraction of the musculus semimembranosis, musculus Sartorius and the musculus vastus medialis (Palmer 1958). However, this compensation results in more joint degeneration, by which it has a negative effect on the joint instead of a positive one (Lewek, Ramsey et al. 2005).
For the stiffness of the collateral ligament applies: the stiffer the ligament, the less ab-/adduction is possible.(Paterno, Hewett 2008) The collateral ligaments can be damaged through an external force, after a sudden displacement of the tibia relative to the femur, secondary to an infection in the joint or secondary after a rupture of the cranial cruciate ligament (Ter Woort, De Busscher et al. 2011, Bruce 1998, Bray, Doschak et al. 1997).

Research has shown that the stiffness of the medial collateral ligament in rats increases with age (Tipton, Matthes et al. 1978), and that the stiffness of the medial collateral ligament in humans is equal to the stiffness of the lateral collateral ligament (Wilson, Deakin et al. 2012). From this, you can conclude that both the collateral ligaments become stiffer as the observed object becomes older and that the femorotibial joint of an older animal will be more stable than the femorotibial joint of a younger object.

Aim of study

The first goal of this study was to determine whether the joint angles and passive range of motion around the mediolateral axis of the femorotibial joint of pigs with a short stride length were significantly different from those with a long stride length. We hypothesise that there is a significant difference.

The second goal of this study was to determine whether the joint angles and passive range of motion around the craniocaudal axis, of the femorotibial joint of older pigs significantly differ from those of younger pigs; the hypothesis there is a significant difference.

Materials and methods

This study was approved by the Ethics Committee of Utrecht University, Utrecht (The Netherlands).

Animals

For this experiment we used twelve pigs, all hybrids from a generation of younglings from a Topigs-20 sow and a D-line boar. The animals, six boars and six sows, were 70 to 81 days old.
The animals were randomly chosen from a population of 45 pigs that were clinically fit, haven't had locomotion problems in the past and they belong to the middle bracket in terms of weight. The 25 per cents lightest pigs had a mean weight of 5.09 kilograms, the mean weight of the middle group was 7.87 kilograms and the 25 per cents heaviest pigs had an average weight of 10.47 kilograms.
Euthanasia was performed after anaesthesia with azaperone[1] (1 ml/5 kg IM) by an intracardial injection of pentobarbital sodium[2] (1 ml/4 kg).

Stride length

To determine the stride length of the pigs, they walked along a test hall while one person exerted some pressure on them to keep walking. This test hall was 165 centimetres long and made of epoxy coating with granules to prevent slipping. The floor was covered with a layer of hand cleaner; this is green soap with grains, in order to determine which movements the stifle joints of the pigs made during slipping (part of another research). The friction coefficient of the whole floor including the hand cleaner is determined to be approximately 0.18-0.34 µ (Vries 2007). The test hall was blocked at both the lateral sides to prevent the pigs from walking to or away from the camera. During the walk in the test hall the animals were filmed from a lateral view; from these recordings eight frames per animal were taken. It didn't matter if the pig walked from the left to the right side of the hall or vice versa. Nevertheless, the steps on the frames had to be made within the area of the test hall and the pig had to be walking on its own without being pushed or touched. Based on these two conditions, eleven of the twelve pigs were divided into two groups. The twelfth pig was not included in neither the continuation of the first nor in the second experiment and is left out of consideration for this research.
The stride length is defined as the distance measured between the position of the leg at the first frame and the position of the same leg at the second frame. The period in-between these two frames is filled with the stance phase and the swing phase of the concerned leg. In this way, the stride length is determined for four steps in total per pig. The stride lengths are measured with a measuring program[3]. Two of the four frames are taken when the pig made a step with its left leg and two frames where taken when it made a step with its right leg. The values found are added together per pig and an average stride length per animal was calculated.

X-ray

The pigs were presented to radiology in pairs as soon as possible after euthanasia. The maximum positions of both femorotibial joints of the eleven euthanized pigs were examined. Each joint was forced into four different positions, namely maximal flexion, maximal extension, maximal abduction and maximal adduction. First, mediolateral radiographs were taken from the normal position of the joint and after that from the maximal extension and maximal flexion. Second, the caudocranial radiographs were taken from the normal position, maximal abduction and maximal adduction respectively. The femorotibial joints of all the pigs were forced by the same person.

Radiographs were taken with a digital x-ray device[4] on the department of Diagnostic Imaging of the faculty Veterinary Medicine, University of Utrecht.
Mediolateral radiographs were taken of the normal position, maximal extension and maximal flexion of the right and left femorotibial joint with the pig lying on its side.

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[1] Stresnil® 40 mg/ml: Elanco Animal Health Eli Lilly The Netherlands; Houten, The Netherlands
[2] Euthasol® 400 mg/ml: ASTfarma BV; Oudewater, The Netherlands
[3] ImageJ® 1.46r: Wayne Rasband, National Institutes of Health; Bethesda, MD, United States
[4] Philips® Bucky Diagnost: Philips Medical Systems DMC GmbH; Hamburg, Germany

Caudocranial x-rays were taken of the normal position, maximal abduction and maximal adduction of the left and right femorotibial joint; with the pigs placed in prone position. In this posture, the plantar sides of the paws were thus the most caudal points of the pig's body.

Determination of joint angles

On each radiograph, two lines were drawn with the aid of imaging software [5]: on the mediolateral radiographs between the greater trochanter and the lateral epicondyle of the femur and between the lateral condyle of the tibia to the lateral malleolus see Jaegger at al. (Jaegger, Marcellin-Little et al. 2002) (see figure 2 and 3).
On the caudocranial the first line was positioned between the centre of the proximal femoral epiphysis and the centre of the distal epiphysis of the femur and the second line was drawn between the centre of the proximal epiphysis of the tibia and the centre of the distal tibia; see Akhmedov et al. (Akhmedov, Sung et al. 2012) (see figure 4).

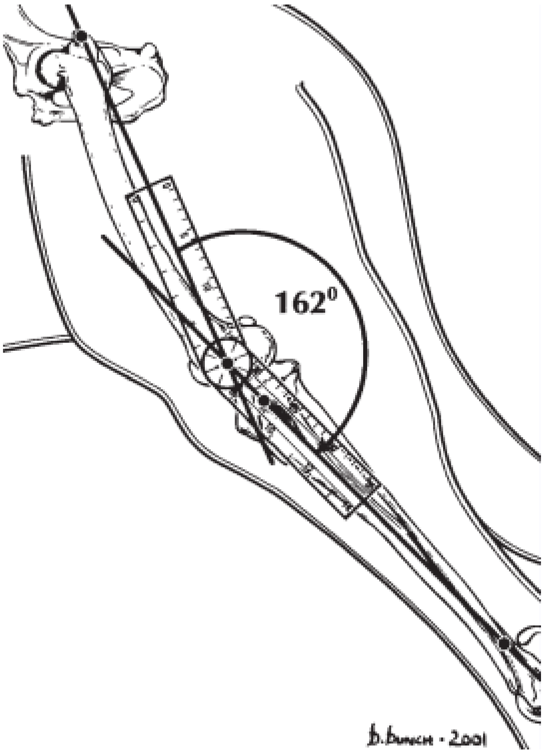

Figure 2. Determination of femorotibial joint angle with joint in maximal extension (Jaegger, Marcellin-Little et al. 2002).

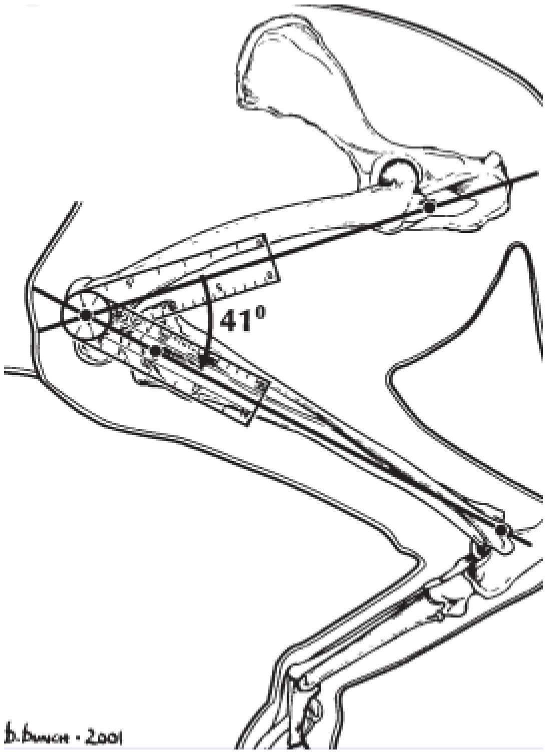

Figure 3. Determination of joint angle with femorotibial joint in maximal flexion (Jaegger, Marcellin-Little et al. 2002).

[5] Impax® Version 6.5.2.657: Agfa Healthcare NV; Mortsel, Belgium

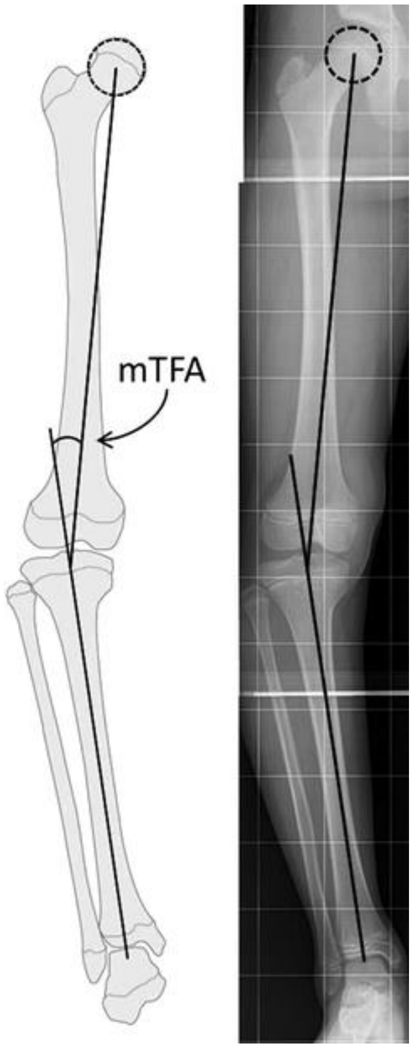

Figure 4. Determination of joint angles in the caudocranial photos (Akhmedov, Sung et al. 2012)

The joint angles were defined as the angle caudal from the point of intersection of the two lines on the mediolateral x-rays; in the caudocranial x-rays, as the angle dorsal from the point of intersection of the two lines.

Statistical analysis

Statistical differences were assessed using the independent samples t-test, for the data that followed a normal distribution, and the Mann Whitney U-test, for the data that were not normally distributed; P-values ≤ 0.05 were considered to be statistically significant. The results are shown as mean ± standard deviation.

Results

The most relevant data of the pigs from this research are shown in table 1. The mean stride length of the total group was 71.85 centimetres; the range of the group 'short stride length' was from 49.85 to 69.40 centimetres, the range of the group 'long stride length' was from 71.48 to 90.07 centimetres. The group 'short stride length' consisted of five pigs, the group 'long stride length' contained six pigs. There was a statistically significant difference ($p<0.05$) between the stride lengths of both groups: 'short stride length' 62.23±7.74, 'long stride length' 79.87±8.98.
The mean age of the total group was 75.7 days; the group 'ten-eleven weeks' comprised pigs varying in age from 70 to 77 days and consisted of five pigs; the group 'eleven-twelve weeks' contained pigs ranging from 77 to 84 days of age, this group included six pigs. There was a statistically significant difference ($p<0.05$) between the ages of both groups: 'ten-eleven weeks' 71.6±1.52, 'eleven-twelve weeks' 79.2±1.47.

Pig number	Gender	Stride length (cm)	Age (days)
4469	Male	59.88	78
4288	Male	71.48	79
4447	Male	66.70	70
4031	Female	49.85	73
4307	Female	65.31	78
4358	Female	90.07	70
2897	Female	71.85	73
4899	Female	86.52	81
4831	Male	87.41	81
4353	Female	71.91	78
4983	Male	69.40	72

Table 1. Pig number, gender, mean stride length and age of the pigs included in this study; n=12.

The measured values obtained from each joint angle are described in table 2. At all joint angles, there was no statistical significant difference between the averages of the values from the left and the right leg. For this reason, the values of both legs were pooled for the remaining statistical provisions of this study.

Joint angle	Left side	Right side	p-value
Neutral position ML	128.45±9.20	121.18±12.91	0.14
Extension ML	132.27±10.57	130.55±10.22	0.70
Flexion ML	66.73±9.04	61.62±5.49	0.13
Range of motion ML	65.55±11.31	68.93±12.22	0.28
Neutral position CC	12.89±6.46	13.88±4.24	0.68
Abduction CC	5.86±4.07	6.64±6.41	0.74
Adduction CC	24.13±7.92	28.88±12.16	0.29
Range of motion CC	18.26±6.30	22.25±9.15	0.25

Table 2. Values (degrees) of the maximum joint angles of the femorotibial joint of pigs.
All values are shown as mean ± standard deviation and were calculated from one measurement per pig.

Slipping and joint angles

The mean, standard deviation and 95% confidence interval of the maximum joint angles in the sagittal plane of the femorotibial joint of the animals from this experiment are shown in table 3. For the calculation of the joint angles of each pig and for the average of each group, the values of the measurements of the left and the right joint are merged.

	Neutral position	Extension	Flexion	Range of motion
Mean	124.82	131.41	64.17	68.05
Stan. Dev.	11.56	10.19	7.75	10.65
95% CI	119.69-129.94	126.89-135.93	60.74-67.61	63.33-72.78

Table 3. Mean, standard deviation and 95% confidence interval (degrees) of the maximum joint angles in the sagittal plane of the femorotibial joint in pigs.
Values were calculated from all of the measurements.

Pig number	Neutral position	Extension	Flexion	Range of motion
4031	130.50	134.00	70.25	63.75
4469	137.00	125.50	72.25	53.25
4447	120.00	140.50	66.05	74.45
4307	136.00	134.50	67.15	67.35
4983	116.00	122.00	55.60	66.40
Mean	127.90	131.30	66.26	65.04
Stan. Dev.	10.92	12.18	9.63	12.36
95% CI	120.09-135.71	122.59-140.01	59.37-73.15	56.20-73.88

Table 4. Mean values (degrees) of the maximum joint angles in the sagittal plane of the femorotibial joint in pigs from the group ‘short stride length’; n= 5.

Pig number	Neutral position	Extension	Flexion	Range of motion
4353	110.00	126.50	58.20	68.30
2897	119.00	137.00	63.20	73.80
4288	125.00	134.00	55.15	78.85
4358	137.00	132.50	62.05	70.45
4899	118.00	119.00	67.50	51.50
4831	124.50	140.00	68.50	71.50
Mean	122.25	131.50	62.43	69.07
Stan. Dev.	11.90	8.76	5.61	11.17
95% CI	114.69-129.81	125.93-137.07	58.87-66.00	61.97-76.16

Table 5. Mean values (degrees) of the maximum joint angles in the sagittal plane of the femorotibial joint in pigs from the group ‘long stride length’; n= 6.

Figure 5 shows the difference between the maximum joint angles and the range of motion of the group ‘short stride length’ and the group ‘long stride length’. The average joint angle of maximum extension is in both groups approximately equivalent, while the average joint angle of the neutral position of the joint and the angle of maximum flexion is smaller in the group of the long stride length than in the group of short stride length (see also table 4 and 5).
There is no statistically significant difference seen between one or more joint angles and/or range of motion of both groups.

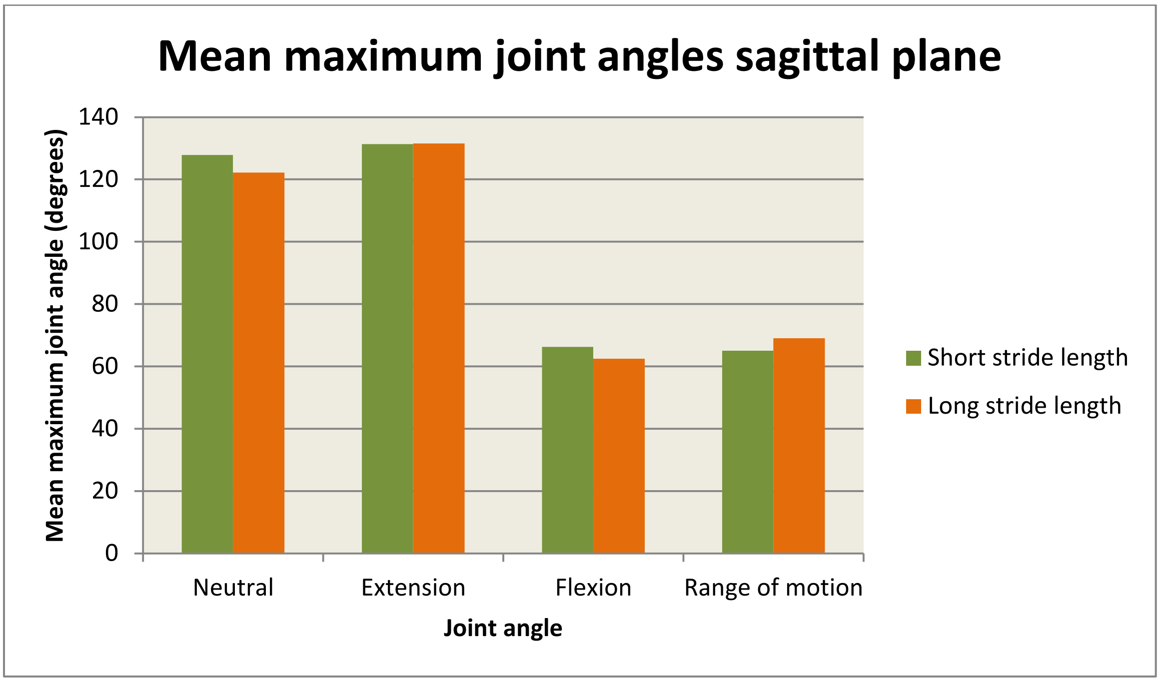

Figure 5. Mean maximum joint angles in the sagittal plane of the femorotibial joint of pigs with a short stride length and pigs with a long stride length.

Stability of the femorotibial joint and age

The mean, standard deviation and 95% confidence interval of the maximum joint angles in the frontal plane of the animals included in this second experiment are shown in table 3. For the calculations of the joint angles, the measured values of both sides are combined to one value, as in the previous experiment.

	Neutral position	Abduction	Adduction	Range of motion
Mean	13.39	6.25	26.50	20.25
Stan. Dev.	5.36	5.26	10.30	7.93
95% CI	11.01-15.76	3.92-8.58	21.94-31.07	16.74-23.77

Table 6. Mean, standard deviation and 95% confidence interval (degrees) of the maximum joint angles in the frontal plane of the femorotibial joint in pigs.
Values were calculated from all of the measurements.

Pig number	Neutral position	Abduction	Adduction	Range of motion
4031	10.75	8.25	29.90	21.65
2897	15.95	13.90	29.75	15.85
4983	16.05	5.15	32.35	27.20
4358	3.50	1.40	26.40	25.00
4447	17.50	12.10	34.65	22.55
Mean	12.75	8.16	30.61	22.45
Stan. Dev.	5.97	5.18	7.36	8.25
95% CI	8.48-17.02	4.45-11.87	25.34-35.88	16.55-28.35

Table 7. Mean values (degrees) of the maximum joint angles in the frontal plane of the femorotibial joint in pigs from the group ‘ten-eleven weeks’; n= 5.

Pig number	Neutral position	Abduction	Adduction	Range of motion
4899	18.55	1.65	17.30	15.65
4831	12.75	5.4	25.15	19.75
4307	11.15	6.00	25.05	19.05
4469	12.35	8.00	23.30	15.30
4288	12.45	-0.45	17.30	17.75
4353	16.25	7.35	30.40	23.05
Mean	13.92	4.66	23.08	18.43
Stan. Dev.	4.99	4.97	11.41	7.51
95% CI	10.75-17.09	1.50-7.81	15.83-30.33	13.65-23.20

Table 8. Mean values (degrees) of the maximum joint angles in the frontal plane of the femorotibial joint in pigs from the group 'eleven-twelve weeks'; n= 7.

In figure 6, the difference in joint angles and range of motion is visible between the group of pigs from ten to eleven weeks and the group containing pigs from eleven to twelve weeks of age. The pigs from ten to eleven weeks of age had on average a smaller angle of the neutral position of the joint, a greater maximum abduction and adduction angle and consequentially, a greater range of motion compared to the averages of the group of pigs from eleven to twelve weeks (see also table 7 and 8).
However, no statistically significant differences were observed between the two groups for any of the variables.

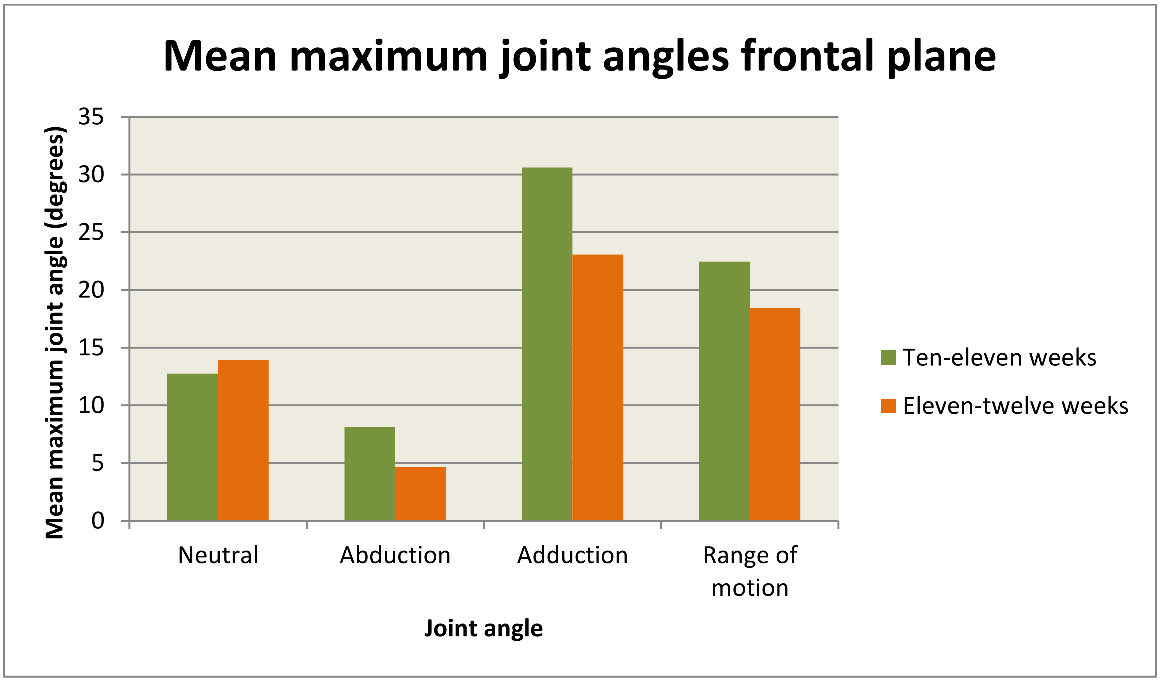

Figure 6. Mean maximum joint angles in the frontal plane of the femorotibial joint of pigs ten-eleven weeks of age and pigs eleven-twelve weeks of age.

Discussion

In this experiment, none of the differences found between the two groups were statistically significant. This is probably due to the fact that the two groups were small in size. For this reason, in further research the groups can be enlarged, to see if this gives a difference in outcome, both numeric and statistical.

The piglets in this study were 70 to 81 days at the time of euthanasia. This age is chosen because the enchondral ossification of the femorotibial joints is not fully completed; this is according to one of the theories about the development of osteochondrose that is accepted by most scientists nowadays (Ytrehus, Carlson et al.). According to this theory there is a disturbance in blood supply of a number of cartilage canals, causing focal necrosis in the cartilage. Because of this necrosis the enchondral ossification cannot be completed in the affected areas, what leads to the primary lesions of osteochondrosis. Since the enchondral ossification of the femorotibial joint of the piglets in this experiment is not yet completed, these piglets are thus free of osteochondrosis manifesta and osteochondrosis dissecans.

In this research, piglets were chosen that belonged to the midsection of the population in terms of weight. By excluding lighter and heavier pigs the results were protected against any distortions caused by possible outliers in weight. The results of this experiment are therefore illustrative for the average weaned pig on a conventional breeding establishment in the Netherlands. The boundaries are set on 24 and 76 per cents of the population to avoid getting a too wide or too narrow range in weight between the selected animals.

In this experiment, x-ray images were used to determine the different joint angles. This seemed like a good method, because in this way the start- and endpoints were clearly visible. However, the endpoints on a number of images were not visible, so the line had to be extrapolated to the suspected endpoint. In this way, less accurate measurements are made compared to when both the start- and endpoints would be completely visible. Also, the program that was used to place the lines was less accurate than expected. When a start- or endpoint was placed half a millimetre off-centre, there was already a difference of a few degrees observed. Therefore, in future research it should be ensured that both the points are visible on the x-ray image and that the chosen points can be selected with more accuracy, for example by zooming in on the start- and endpoints. A goniometer could also be used instead of x-rays; a study done by Jaegger et al. (2002) showed that the results obtained by this method are equal to the results obtained with the aid of x-rays (Jaegger, Marcellin-Little et al. 2002).

While taking the x-ray images the femorotibial joints of all animals were forced in maximal position. This was done by the same person, whereby the sequence of actions remained the same (consecutively normal position mediolateral, forcing maximal extension, forcing maximal flexion, normal position caudocranial, forcing maximal abduction and forcing maximal adduction of the right leg, after that normal position caudocranial, forcing maximal abduction, forcing maximal adduction, normal position mediolateral, forcing maximal extension and forcing maximal flexion of the left leg). Be keeping the person who forces the joints and the sequence of actions equal for all animals, the margin of error remains the same and the results could thus be compared with each other.

Slipping and joint angles

Based on the results of this experiment, we cannot distinguish piglets with large joint angles from piglets with small joint angles on the basis of stride length. Several studies have raised the suggestion that biomechanical factors have an influence on the development of osteochondrosis in pigs (Ytrehus, Carlson et al. , Grevenhof, Ott et al.). These biomechanical factors include trauma to the joint and slipping in the sagittal plane (Nakano, Brennan et al. 1987, Grevenhof, Ott et al.). In this experiment, we showed that stride length has no influence on the joint angles, and that the freedom of movement is thus equal for both groups. To find a possible relation between slipping and osteochondrosis, research should be done on whether the frequency and severity of osteochondrosis differs between pigs with a short stride length and pigs with a long stride length.

The length of the test hall in this study was 165 centimetres. In further research a longer test hall could better be used, in order to analyse more frames per piglet. As a consequence, a more reliable stride length can be calculated and piglets that are expelled from the recent study because they did not have enough useable frames might meet this demand in a study with a longer test hall and then could be included in that study.
The test hall in this study was covered with hand cleaner, causing the slip resistance to get a lower classification (slip resistance without hand cleaner is approximately 0.34-0.51 μ (Vries 2007)). The slip resistance of the stable floor where the piglets usually walk is approximately 0.34-0.71 μ. This big dispersion is because the floor gets more slippery when it becomes wetter. Due to the fact that the piglets spread their faeces partly on the concrete floor via their legs and claws, the slip resistance of the floor becomes lower and the piglets will slip earlier. The slip resistance of the stable floor is thus equal to or higher than the slip resistance of the test hall floor. The piglets will probably have a higher frequency of slipping on this floor than the slip frequency on the stable floor. However, the stable floor is wetter at the end of the rearing period on the breeding company than it was when the piglets first came in after they were weaned. The animals will slowly have adapted their stride length to the more slippery floor. The difference in slip resistance between the floor of the test hall and the stable floor during the rearing period is so minimal that it is very likely that this difference will not have resulted in a further shortening of the stride length. To be certain about this, floors with a diversity of slip resistance have to be used in further research; the slip resistance of the floors has to vary from one equal to that of a clean stable floor to one that is comparable to a dirty stable floor on the end of the rearing period.

The stride length in this research is determined for each pig by taking the mean out of four steps measured. By taking the average of several measurements instead of taking just one measurement a correction is conducted for any differences in stride length, making the stride length per pig more reliable. One of the causes that can lead to differences in stride length is anatomy; due to a difference in the skeleton of a pig, a distorted spine for example, there could be a difference in stride length between the left and the right hind limb. Another cause of stride length differences is a discrepancy between the lengths of the two hind limbs. If a pig has one hind limb that is shorter than the other, the stride length of the shorter limb will be reduced compared to the stride length of the longer limb. For the foregoing reasons an equal number of steps of the left and the right hind limbs are measured so that the average stride length of each pig cannot be influenced by a difference in stride length between the limbs. However, a difference in stride length caused by a painful process in either the limb or the claw is impossible, because the concerned pig would have been limping and for that reason would have been excluded earlier on in the study. Likewise, the possibility that osteochondrosis is the cause of a difference in stride length due to mechanical obstruction or pain is excluded, because the pigs in this study are up to now free of osteochondrosis visible on radiographs considering their age. If there were pigs with large cartilage defects in the femorotibial joint at the time of euthanasia, they would not yet have had pain due to this osteochondrosis latens (Ytrehus, Carlson et al.).

Stability of the femorotibial joint and age

In this experiment, on average the pigs ranging from ten to eleven weeks had numerically a larger angle of maximum adduction and thereby also a greater range of motion compared to pigs from eleven to twelve weeks. These findings correspond with the hypothesis that the collateral ligaments become stiffer as the animal grows older, like the research of Tipton et al. (1978) showed. However, the differences between the two groups are not statistically significant. The rats in the study of Tipton et al. were 15 days to 2 years old. Since rats are earlier mature than pigs, the ages of the rats in the study are approximately equal to ages of 45 days to 6 years when converted to pigs. In the current study there was a maximal age difference of 2 weeks between the two groups, what could have been the reason that no significant difference in stiffness was found. Therefore, future research has to be carried out with larger groups and with greater differences in age between the groups; it is even better to carry out a research for a longer period or to include different groups of age (for instance, the youngest

group is 1.5 months, the second group is 6 months older than the youngest group, the third group is 6 months older than the second group and so on until the oldest group of 73.5 months).
This research should show whether the joint angles and range of motion in the frontal plane significantly decrease as the animals age and whether the hypothesis of the stiffening of collateral ligaments through time could also be applied to pigs.

If the collateral ligaments become stiffer when the animal ages, the femorotibial joint will be more stable. The chance of injury to the collateral ligaments is, however, then also greater. This is due to the loss of elasticity, resulting in a loss of stretching possibilities to medial or lateral when the animal makes a wrong movement. Examples of these movements are slipping in the frontal plane or the unexpected rotation of the femur while the tibia remains in position, as can happen when the animal runs and unexpectedly comes on a slippery part of the floor. In dogs, an injury of a collateral ligament is almost always seen with damage to one or more of the other ligaments of the stifle joint (Laing 1993). As a result, the stifle joint will be more unstable, which can lead to an increase in abnormal movements of the joint (Paterno, Hewett 2008). Due to these movements, there can be a local overload in the joint, which can lead to osteochondrosis (Nakano, Brennan et al. 1987). The frequency of injuries to the ligaments of the stifle joint with clinical symptoms is not known in pigs, nor is the effect of these injuries on the load in the joint and the resulting prevalence of osteochondrosis. Firstly, more research must be done to find out if the collateral ligaments of pigs become stiffer when the pig gets older. If this hypothesis is proved, research must be carried out on the clinical appearance of lesions of the ligaments and their effects on the stifle joint, before anything can be said concerning the relevance of changing joint angles in time in relation to osteochondrosis.

Conclusion

The research questioned whether the joint angles and range of motion in the sagittal plane of the femorotibial joint were different between pigs with a short stride length and pigs with a long stride length, and whether such a difference would be found between the joint angles and range of motion of the frontal plane of young pigs and older pigs.

The results of this study show that there is no significant difference between sagittal joint angles and range of motion in pigs with a short and pigs with a long stride length, nor between the joint angles and range of motion in the frontal plane of young pigs and older pigs.

Repeating this study with larger groups could give more proof on whether there really is no significant difference between the groups.

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