Open Journal of Veterinary Medicine, 2015, 5, 61-67
Published Online March 2015 in SciRes. http://www.scirp.org/journal/ojvm
http://dx.doi.org/10.4236/ojvm.2015.53008

Foreleg Bending in Blue Foxes (*Vulpes lagopus*) as Evaluated by Radiography

Hannu T. Korhonen, Pekka Eskeli, Hanna Huuki, Juhani Sepponen

Natural Resources Institute Finland (Luke), Kannus, Finland
Email: hannu.t.korhonen@luke.fi

Received 9 February 2015; accepted 3 March 2015; published 11 March 2015

Abstract

The aim was to compare radiographic X-ray data to foreleg bending, moving difficulties and body size in juvenile blue foxes. Experimental groups were: 1) restricted feeding, Ca:P ratio 1.5:1 (R 1); 2) restricted feeding, Ca:P ratio 2.9:1 (R 2); 3) restricted feeding Ca:P ratio 2.0:1 control level (R 3); 4) *ad libitum* feeding, Ca:P ratio 1.5:1 (AL 1); 5) *ad libitum* feeding, Ca:P ratio 2.9:1 (AL 2); 6) *ad libitum* feeding Ca:P ratio 2.0:1 control level (AL 3). Moving difficulties and foreleg bending were evaluated in live animals. At pelting, left foreleg was removed. X-ray pictures were taken from lateral views. Dimensions of ulna and radius were measured from the X-ray pictures. Conditions of carpal joint and elbow joint were visually evaluated. The results showed that final body weight was affected by feeding intensity (P = 0.001). *Ad libitum* fed animals had more moving difficulties compared to restricted ones (P = 0.001). The Ca:P ratio tended (P = 0.06) to have an effect on feet bending. Bending was greatest in low Ca:P ratio (1.5:1) and, correspondingly, least in high Ca:P ratio (2.9:1). Moving difficulties were most common in heaviest animals. The moving difficulties tended (P = 0.07) to be positively related to feet bending. Maximum width of ulna was lowest in low Ca:P ratio diet (1.5:1). Bending was negatively correlated with maximum width of ulna. It can be concluded that low Ca:P ratio in the diet (1.5:1) increases foreleg bending in juveniles. Moving difficulties are related to foreleg bending and high body weight.

Keywords

***Vulpes lagopus*, Foot Welfare, Moving Difficulties, Feet Bending, Blue Fox**

1. Introduction

Pronounced bending of forelegs is a common phenomenon in farm bred blue foxes (*Vulpes lagopus*) today [1]. Although the exact cause is unknown, excessive nutrition and body mass, rapid growth and a hereditary component are suspected to be contributing factors. The body size of farm-raised blue foxes has dramatically increased

How to cite this paper: Korhonen, H.T., Eskeli, P., Huuki, H. and Sepponen, J. (2015) Foreleg Bending in Blue Foxes (*Vulpes lagopus*) as Evaluated by Radiography. *Open Journal of Veterinary Medicine*, **5**, 61-67.
http://dx.doi.org/10.4236/ojvm.2015.53008

during the last decades. Nowadays foxes can weigh more than 20 kg where as 15 - 20 years ago their average weight was less than 10 kg [2]. It is assumed that strong selection of large body size is linked with developmental disorder of bones and joints [3]. This is a common problem, for example, in large size dog breeds [4]-[6]. It has led to a physiological adaption with increased levels of growth hormone (GH) and IGF. It may also be connected to poor mineralization of bones [7]. One crucial component in the diet may be the proper Ca:P ratio [8]-[11]. There has been little research on whether the Ca content in modern fox feed is still sufficient to promote a healthy bone growth in large foxes, and whether there are other components in modern feed recommendations that need to be changed to better meet the nutrient requirements of modern foxes. However, foreleg bending has become a potential welfare problem in blue foxes [1]. Therefore, it is outmost import to understand this problem in more details.

In our previous study [2], we presented data on the effects of *ad libitum* and restricted feeding with three Ca:P ratio diets on foot welfare in blue foxes. Detailed description of feet bending, ability to move and behavior were given in relation to body weight gain from weaning to pelting. In the present study, we provide more detailed information about the feet bending in juvenile foxes. A radiographic examination (X-ray) was done from forelegs of those animals employed in our previous study [2]. The aim here was to correlate the X-ray analyses data with visual foreleg bending data, moving difficulties and body size.

2. Material and Methods

This study was carried out at MTT Agrifood Research Finland, Kannus, in western Finland (63.54˚N, 23.54˚E). The use of experimental animals was evaluated and approved by the Animal Care Committee of Etelä-Suomen aluehallintoviras to (ESAVI/PH 1231 A/2013). The general health of animals was visually checked daily.

2.1. Experimental Set-Up and Animals

Animals and experimental set-up used for analyses in the present study are described in details by [2]. Shortly, the following set-up was employed: Experimental animals were juvenile male blue foxes born in May 2013. Experiment started at weaning on August 6th and finished at pelting on November 26th. The effect of restricted and *ad libitum* feeding, as well as the Ca:P ratio, on body mass, bending of feet and moving difficulties were studied. The following experimental groups were compared: 1) restricted feeding, Ca:P ratio 1.5:1 (R 1); 2) restricted feeding, Ca:P ratio 2.9:1 (R 2); 3) restricted feeding Ca:P ratio 2.0:1 control level (R 3); 4) *ad libitum* feeding, Ca:P ratio 1.5:1 (AL 1); 5) *ad libitum* feeding, Ca:P ratio 2.9:1 (AL 2); 6) *ad libitum* feeding Ca:P ratio 2.0:1 control level (AL 3). The amount of restricted feeding was set to be 60% - 70% of *ad libitum* level.

Animals from same genetic background (same mother) were evenly distributed to each study group. Littermates were placed equally to groups to homogenize the genetic variability. Body weights were measured with a Mettler SM 15 balance, accuracy ±10 g.

Animals were pair-housed in standard wire-mesh cages measuring 105 cm long × 120 cm wide × 70 cm high. Each cage was furnished with a wire-mesh platform (105 cm long × 25 cm wide) located at 23 cm from the ceiling. A bone (30 cm long × 7 cm diameter) was placed into cage floor as chewing and activity object.

2.2. Evaluation of Foreleg Carpal Joints and Moving

The foreleg carpal joint angle, as an indicator of leg weakness, and the fox's ability to move about in the cage were evaluated both live and from video recordings. For details, see [2]. The subjective evaluation of foreleg bending was done by one evaluator on a scale of 1 - 5 [2] [12]. In the worst case (score 5 = very poor), the carpal joint was bended to a 90˚ angle compared to normal, only slight angled carpal joint (score 1 = excellent). Ability to move was evaluated as follows: If there were no difficulties to move, situation was scored to be 0. The animal was actively moving about in the cage and was able to jump easily on to the platform. Mild difficulties to move were scored as 1. The fox sometimes moved about in the cage and was somehow capable of jumping on the platform, but clearly had some difficulties or unwillingness to move. Marked difficulties (score 2), *i.e.* the fox remained sitting or lying still in the cage, even when encouraged to move, were not found.

2.3. Radiographic Examination

At pelting, left foreleg was removed and stored at −20˚C until radiographic examination (X-ray). Radiological examination was carried out at Nikula Hevosklinikka, Kaustinen, by an experienced veterinary surgeon. X-ray pictures were taken from lateral views by using Ajex 9015 HF portable X-ray machine (Ajex Meditech LTD., Blackhills, USA) at 70 kW with 0.2 sec exposure time. Maximum and minimum width of ulna and radius were measured from the X-ray pictures. Condition of carpal joint and elbow joint were visually evaluated.

2.4. Statistical Analyses

The statistical analyses were carried out using SAS/STAT software, Version 9.2 of the SAS System for Windows. Copyright© 2009, SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

Measurements of *ulna* and *radius* were analysed using the following linear mixed model:

$$\mathrm{Y}_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij}$$

where μ was the general mean, α_i was the fixed effect of feeding intensity (R or AL), β_j was the fixed effect of Ca:P ratio (1.5:1, 2.9:1, and control level 2.0:1) and $(\alpha\beta)_{ij}$ was the interaction between fixed effects. ε_{ij} was the residual error. Normality of residuals was checked for each analysis using scatter plots of residuals and fitted values.

Correlations between each parameter were calculated using Spearman correlations, since some of the parameters (e.g. bending of feet and ability to move) were not normally distributed.

3. Results

Dimensions of ulna and radius in relation to feet bending, moving difficulties and body weights are given in **Table 1**. Feeding intensity or Ca:P ratio did not affect maximum or minimum width of radius. Furthermore, feeding intensity did not significantly affect maximum width of ulna. A tendency (P = 0.09) was found that maximum width of ulna was affect by diet, being highest (10.86 mm) in controls (Ca:P ratio 2.0:1) and lowest in foxes with Ca:P ratio 1.5:1, *i.e.* 10.42 mm on an average. Minimum width of ulna was not affect by Ca:P ratio. However, it was affected by feeding intensity (P = 0.04; **Table 1**).

Final body weight was affected by feeding intensity, *i.e*. body weights were significantly higher (P = 0.001) in *ad libitum* fed animals. Moving difficulties were affected by feeding intensity, *i.e. ad libitum* animals were having significantly more moving difficulties compared to restricted ones (P = 0.001). Feeding intensity did not affect the bending of feet. However, Ca:P ratio tended (P = 0.06) have an effect on feet bending. Bending was highest in low Ca:P ratio (1.5:1) and lowest in high Ca:P ratio (2.9:1).

The visual evaluation of carpal and elbow joints did not reveal any damages or disorders in those areas. Bowing of ulna and radius was not seen in radiographic examination. Examples of X-ray pictures are shown in **Figure 1** and **Figure 2**.

Table 2 provides cross correlations between studied variables. A positive very significant correlation was found between moving difficulty and final body weight. Moving difficulties were most common in heaviest animals and *vice versa*. Bending of the feet was negatively correlated with maximum with of ulna, indicating that most bended foreleg has lowest width of ulna. Moving difficulties tended (P = 0.07) to be positively correlated to bending of feet. Maximum width of ulna correlated positively with minimum width of ulna. Minimum width of ulna correlated with minimum width of radius. Furthermore, maximum width of radius correlated positively with minimum width of radius. Initial body weight was correlated with minimum width of ulna and maximum width of radius.

4. Discussion

One of the most common medical diagnostic procedures is radiography or X-rays. The greatest benefit of X-rays is their ability to penetrate tissues and show internal structures [7]. In the case of legs, the X-rays will be almost fully absorbed by the bones, while the muscles and ligaments will absorb varying amount of X-rays. The resulting image will be one of the white bones including black air surrounding the leg and various shades of grey representing muscles etc. In the present study, we used X-ray analyses to evaluate condition of foreleg bones and joints in blue foxes. This is now first time when this kind of analyses was done in farmed foxes. According to author's best knowledge, no previously published data are available.

Table 1. The mean maximum and minimum width of ulna and radius is presented in millimeters. Standard deviations (SD) in parenthesis. Final and initial body weights in grams. The level of bending of feet was evaluated according to scale 1 - 5 where 1 = excellent, 2 = good, 3 = sufficient, 4 = poor, 5 = very poor. The bending is presented as a number of animals with bended feet in a group. Moving difficulties is presented as a number of animal having slight moving difficulties. P_1 = significance between restricted and *ad libitum* groups; P_2 = significance between Ca:P levels; P_3 = significance between their interactions. R 1: restricted feeding, Ca:P ratio 1.5:1; R 2: restricted feeding, Ca:P ratio 2.9:1; R 3: restricted feeding Ca:P ratio 2.0:1 control level; AL 1: *ad libitum* feeding, Ca:P ratio 1.5:1; AL 2: *ad libitum* feeding, Ca:P ratio 2.9:1; AL 3: *ad libitum* feeding Ca:P ratio 2.0:1 control level.

Variable	R 1	R 2	R 3	AL 1	AL 2	AL 3	P_1	P_2	P_3
$Ulna_{max}$ width	10.56 (0.53)	10.60 (0.52)	10.50 (0.53)	10.30 (0.48)	10.33 (0.53)	11.22 (0.83)	ns	0.09	0.04
$Ulna_{min}$ width	4.56 (0.81)	4.75 (0.86)	4.50 (0.47)	4.55 (0.60)	3.94 (0.53)	4.22 (0.51)	0.04	ns	ns
$Radius_{max}$ width	9.56 (0.53)	9.90 (1.29)	10.00 (0.47)	9.80 (0.42)	9.06 (0.39)	9.67 (0.87)	ns	ns	0.08
$Radius_{min}$ width	4.50 (0.83)	4.60 (0.88)	4.35 (0.71)	4.55 (0.83)	4.06 (0.46)	4.33 (0.71)	ns	ns	ns
Final body weight[a]	13374 (1701)	14079 (1247)	12775 (1449)	18922 (1597)	17834 (2398)	17316 (2213)	<0.001	ns	ns
Initial body weight[a]	5105 (325)	5214 (229)	5193 (352)	5106 (462)	5184 (488)	5233 (824)	ns	ns	ns
Moving difficulties	1	1	0	9	6	4	<0.001	ns	ns
Bending									
Score 4[a]	6	1	7	8	6	3			
Score 3[a]	2	8	1	2	4	6	ns	0.06	ns
Score 2[a]	2	1	2	0	0	1			

[a]Original data presented in [2].

Table 2. Calculation of cross correlation (Spearman) between different parameters. Statistical significance: $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; $^{a}P = 0.07$.

	$Ulna_{max}$	$Ulna_{min}$	$Radius_{max}$	$Radius_{min}$	Final BW	Initial BW	Bending
Moving	0.134	−0.027	0.020	0.069	0.574^{***}	0.066	0.236^{a}
$Ulna_{max}$		0.352^{**}	0.215	0.306^{*}	0.109	0.218	$−0.275^{*}$
$Ulna_{min}$			0.621^{***}	0.705^{***}	0.012	0.304^{*}	−0.055
$Radius_{max}$				0.575^{***}	0.001	0.259^{*}	0.052
$Radius_{min}$					0.166	0.169	−0.045
Final BW						0.184	0.097
Initial BW							0.052

Figure 1. X-ray picture of foreleg. Group AL 2 (Ca:P ratio 2.9:1). Body weight 19.805 kg. Bending score = 4.

Figure 2. X-ray picture of foreleg. Group R 1 (Ca:P ratio 1.5:1). Body weight 14.235 kg. Bending score = 2.

The present study material was based on two feeding levels, *i.e. ad libitum* and restricted ones. Furthermore, it included data from animals fed with three different Ca:P ratios, *i.e.* 1.5:1, 2.0:1 and 2.9:1. So, we had wide range of study material to evaluate foreleg-bending influences. Our X-ray pictures did not reveal any curving of ulna and radius bones. Bending of foreleg seen in live animals is thus not due to curving of these bones *per se*, but is mainly a result of pronounced bending in the area of carpal joint. Some bending may also occur around elbow joint.

Growing period including actual development of skeleton bones and joints is in blue foxes from weaning in July to mid-September. Thereafter, actual body fattening process will begin [2]. Juvenile foxes will produce excessive subcutaneous fat mainly from October onwards. Finally, pelting is carried out in late November [13] [14]. Most pronouncedly bended forelegs, related to excessive body weights, will occur during October-November [2]. This is actually a rather short period of time to have an influence on foreleg condition and welfare.

Bending of front feet was evaluated in live animals by a 5-point scale. However, the extreme cases of very badly bended foot (score 5) nor perfectly straight feet (score 1) were not found in the present study. Comparison here was thus between score points 2, 3 and 4. Our X-ray pictures did not reveal any damages or disorders in studied foreleg bones and joints. In this study feet bending with score points 2, 3 and 4 did not cause any X-ray detectable changes on foreleg bones and joint in case of juveniles. According to [1], the amount of foxes with worse bending on fur farms averages nowadays 14%. Further studies will be needed to clarify the welfare effects of foreleg bending in those animals, and whether or not the condition causes pain.

Two previous studies [10] [11] are available in which dietary Ca and P concentrations did not have any effect on bone mineralization or breaking strength in juvenile blue foxes. Study by [8], on the other hand, reported that dietary Ca and P have certain impact on the mineralization of bones; low Ca:P ratio in the diet significantly reduced the Ca and P concentrations of ulna bones compared with the normal dietary Ca:P ratio. Despite of lower mineralization, however, significant differences in breaking strength of ulna were not found. Furthermore, no relationship was found between Ca level and foot bending. It was concluded that the calcium level in bones is either not directly related to foot bending or lowering of Ca level was not enough to cause any measurable effects. In the present, mineral content of bones was not measured. Therefore, we do not know how diet Ca:P content affected on bone mineral content. Dimensions of radius were not affected by Ca:P ratio in the diet. However, maximum width of ulna was lowest in low Ca:P ratio (1.5:1). Correspondingly, early study [8] showed that there was a greater bone thickness in foxes fed on a high Ca diet. They also noticed that low dietary Ca caused bowing of legs. In the present study, most pronounced bending was also noticed with low Ca:P ratio.

Our correlation data confirmed the result of our previous study [2] that moving difficulty is highly related to body weight of animals. Thus, large-sized foxes with high final weight are typically having moving difficulties the most. Correlation data also revealed that moving difficulty tended to be related to bending of feet—a new finding which did not come out in our previous analyses [2]. Thus, it seems obvious that moving difficulties are explained at least by two factors, *i.e.* high body weight and bending of foreleg. Furthermore, bending here tended to be related to Ca:P ratio. Animals with low Ca:P ratio used to have most bended forelegs. We are tempted to conclude, that Ca:P ratio, to a certain extent, could be one of the reasons for bending of feet. Together with high body weight, bending of the front feet can cause moving difficulties.

5. Conclusion

Low Ca:P ratio in the diet (1.5:1) might increase foreleg bending in juvenile blue foxes. However, in this study, foreleg bending (score points 2, 3, 4 in scale 1 - 5) was not found to cause disorders to bones or joints of foreleg. Moving difficulties seem to be related to foreleg bending and high body weight in late autumn. Further studies are needed to confirm the welfare effects of bending of feet. Bending, however, seems to be linked with moving difficulties, which may jeopardize animal's wellbeing.

Acknowledgements

This study was financially supported by the Finnish Fur Breeders' Association and MTT Agrifood Research Finland. Special thanks to Nikula Hevosklinikka for valuable aid in radiography.

References

[1] Ahola, L., Huuki, H., Koistinen, T. and Mononen, J. (2014) Eläinten hyvinvointi kettutiloilla: Tuloksia tilakäynneiltä. Itä-Suomen yliopisto, Biologian laitos ja Maaja elintarviketalouden tutkimuskeskus MTT, Kotieläintuotannon tutkimus,

107.

[2] Korhonen, H.T., Eskeli, P., Lappi, T., Huuki, H. and Sepponen, J. (2014) Effects of Feeding Intensity and Ca:P Ratio on Foot Welfare in Blue Foxes (*Vulpes lagopus*). *Open Journal of Animal Sciences*, **4**, 153-164. http://dx.doi.org/10.4236/ojas.2014.44020

[3] Smith, C.W. (1991) Osteochondrosis in the Dog—Diagnosis, Treatment, and Prognoses. *Canine Practice*, **16**, 15-22.

[4] Grondalen, J. and Lingaas, F. (1991) Artrosis in the Elbow Joint of Young Rapidly Growing Dogs: A Genetic Investigation. *Journal of Small Animal Practice*, **32**, 420-464.

[5] Beale, B.S. (1999) Osteochondrosis in Dogs: Surgical Indications and Consideration. *Proceedings of the North American veterinary Conference*, **13**, 471-472.

[6] Brianza, S.Z.M., Delisem M., Ferraris, M.M., D'Amelio, P. and Botti, P. (2006) Cross-Sectional Geometrical Properties of Distal Radius and Ulna in Large, Medium and Toy Breed Dogs. *Journal of Biomechanics*, **39**, 302-311. http://dx.doi.org/10.1016/j.jbiomech.2004.11.018

[7] Korhonen, H.T., Happo, M., Rekilä, T., Valaja, J. and Pölönen, I. (2005) Effects of Diet Calcium:Phosporus Ratio and Metabolizable Energy Content on Development of Osteochondrosis, Foot Bending and Performance in Blue Foxes. *Animal Science*, **80**, 325-331. http://dx.doi.org/10.1079/ASC40620325

[8] Harris, L.E., Basett, C.F. and Wilke, C.F. (1951) Effect of Various Levels of Calcium, Phosphorus and Vitamin D Intake on Bone Growth. I. Foxes. *Journal of Nutrition*, **43**, 153-165.

[9] Bassett, C.F., Harris, L.E. and Wilke, C.F. (1951) Effect of Various Levels of Calcium, Phosphorus and Vitamin D Intake on Bone Growth. II. Minks. *Journal of Nutrition*, **44**, 433-442.

[10] Valaja, J., Pölönen, I., Jalava, T., Perttilä, S. and Niemelä, P. (2000) Effect of Dietary Mineral Content on Mineral Metabolism and Performance of Growing Blue Foxes. *Scientifur*, **24**, 28-31.

[11] Valaja, J., Pölönen, I., Rekilä, T., Nenonen, N. and Jalava, T. (2002) Calcium and Phosporus Nutrition of Blue Foxes. NJF-Seminar No. 347, 2-4. October 2002, Vuokatti, 8.

[12] Kempe, R., Koskinen, N., Mäntysaari, E. and Stranden, I. (2010) The Genetics of Body Condition and Leg Weakness in the Blue Fox (*Alopex lagopus*). *Acta Agriculturae Scandinavica*, **60**, 141-150. http://dx.doi.org/10.1080/09064702.2010.515241

[13] Korhonen, H.T. and Orjala, H. (2010) Effect of Cage Dimensions on Welfare and Production of Farmed Blue Fox. *Annals of Animal Science*, **10**, 311-324.

[14] Korhonen, H.T., Jauhianen, L. and Rekilä, T. (2007) Comparison of Blue Fox Housing in Shed and Hall Environment. *Annals of Animal Science*, **7**, 23-34.