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Radiographic Assessment of Bone Cortex to Bone Diameter Ratio of Radius, Tibia, Metacarpus, Metatarsus and Proximal Phalanx of Fore and Hindlimbs in Minature Donkey

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Abstract

Objective - The aim of this study was to measure the ratio of bone cortex (C) to bone diameter (D), (C/D) in radius/tibia, metacarpus /metatarsus and proximal phalanges in fore and hindlimbs to be used as a diagnostic guide in metabolic and nutritional diseases in Minature Donkey.
Design- Experimental study
Animals- Eight adult Minature donkeys.
Procedures- Lateromedial, dorsopalmar and dorsoplantar radiographs of eight fore and hindlimbs of Miniature donkeys were studied. Cortical thickness, bone diameter and C/D ratio of mid radius/tibia regions, mid metacarpal/metatarsal regions and mid proximal phalanx of forelimb/ mid proximal phalanx of hindlimb regions were measured. Data were analyzed statistically and mean, standard errors and P-values were obtained**.**
Results- C/D ratios of mid radial region, mid metacarpal region and mid proximal phalanx of forelimb in lateromedial view were 0.54 ± 0.02, 0.58±0.02 and 0.54±0.03 respectively. C/D ratios of mid tibia region, mid metatarsal region and mid proximal phalanx of hindlimb in lateromedial view were 0.56±0.01, 0.65±0.02 and 0.54±0.05 respectively. C/D ratios of mid radial, mid metacarpal and mid proximal phalanx regions of forelimb in dorsopalmar view were 0.55±0.03, 0.6±0.01 and 0.55±0.02 respectively. C/D ratios of mid tibia, mid metatarsal and mid proximal phalanx regions of hindlimb in dorsoplantar views were 0.49±0.02, 0.57±0.02 and 0.55±0.04 respectively.
Conclusion and Clinical Relevance- This study showed that there were no significant differences between C/D ratios in any of the regions. The cortex and diameter in lateromedial view between metacarpal – metatarsal regions and cortical thickness of proximal phalanx of forelimb - hindlimb regions showed significant difference (P<0.05).
Key Words- Radiography, Bone cortex to diameter Ratio, Forelimb, Hindlimb, Miniature Donkey.
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Introduction

The distal forelimbs are more susceptible to injury than other structures and contributed to 75% of all forelimb injuries.[1] Furthermore, the fetlock joint is one of the most common sites of injuries in the equine forelimb. [2,3] Bone densitometry is not a routine method in veterinary medicine.[4] During the growth and remodeling of bone, a parts of the bone. An intervening layer of cortical bone is not involved. A converse process of periosteal conversion directly into medullary connective tissue can also occur without an intermediate stage of ossification.[5] Age-related bone loss and postmenopausal osteoporosis are disorders of bone remodeling, in which less bone is reformed than resorbed. Yet, this dysregulation of bone remodeling does not occur equally in all bone regions. Loss of bone is more pronounced near and at the end of the cortex leading to cortical wall thinning and medullary cavity expansion, a process sometimes referred to as "trabecularisation" or "cancellisation". Cortical wall thinning is of primary concern in osteoporosis due to the strong deterioration of bone mechanical properties. It has been found that bone loss is accelerated near the endocortical wall where the specific surface is highest. Over time, this leads to a

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substantial reduction of cortical wall thickness from the endosteum.[6] It is well known that cortical porosity of bone increases in osteoporosis leading to a reduction in bone stiffness and strength, ultimately increasing the risk of fracture.[7]

Different studies have done on osteometry and osteomorphology of forelimbs in the horse.[8,9,10,11,12] Although the changes in the focus-film and object-film distances can lead to the magnification of the objects on the film,[13] several studies have involved the use of radiographs to measure some human and animal bones.[10, 12, 14,15] Many authors photographed horses with skin markers to measure some equine joint angles and bone dimensions.[5,16]

Normal radiography cannot detect the reduction in bone density when it is less than 30% of the normal one. C/D ratios are useful method for evaluation of the bone health. These ratios do not use routinely for animals such as camel because of its price and some other problems.[17]

This study was performed to obtain to some normal values of C/D ratios in fore and hind limb in Miniature donkey.

Materials and Methods

All procedures involving the experimental use of animals were approved by the Animal Ethics Committee, a branch of the Research Council of the Veterinary School in Shahid Bahonar University, Kerman Province, Iran, and administered by the National Animal Ethics Advisory Committee. Eight four to five - year - old healthy Miniature donkeys with no apparent problem in their limbs were selected. Left animal fore and hind limbs were collected from animal slaughter of Kerman zoo during 3 month. Mid part of radius, metacarpus and 1st phalanx of forelimbs and tibia, metatarsus and 1st phalanx of hind limbs were radiographed in lateromedial and dorsopalmar/ dorsoplantar views using 60 kVp and 5 mAs with FFD of 80 cm (Toshiba Xvision EX, Japan). The thicknesses of bone cortices and diameters in radiographs were measured using digital scanning software (Sigma scans Pro 5.0, SPSS Science, Chicago, IL). The mean of the both cortices diameter was calculated and used for each animal. The C/D ratio of mid radius, tibia, metacarpal/metatarsal region and first phalanges of fore and hind limbs were measured in both views (Fig. 1,2,3).

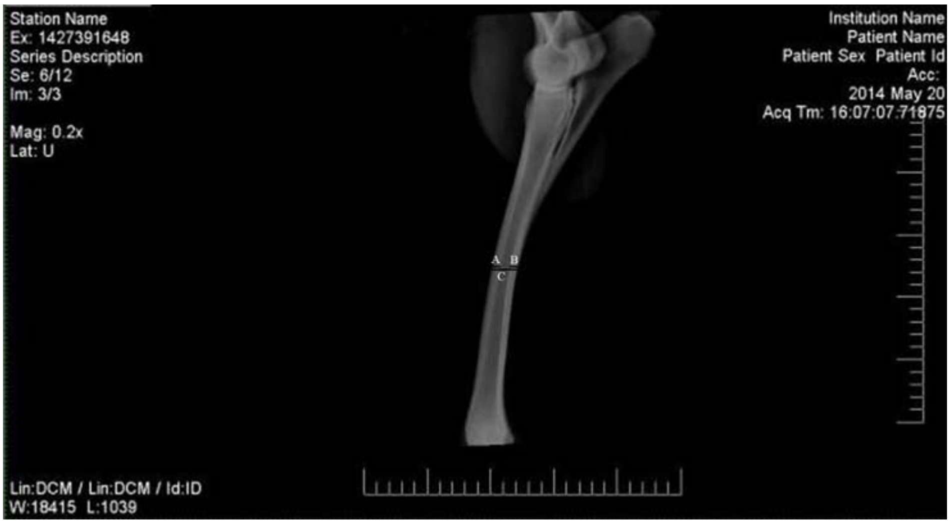

Figure 1- C/D ratio measurement in lateromedial view of radius. Cortical thickness (A & B) and diameter (C) of radius are shown. C/D = $\frac{A+B}{C}$.

Figure 2- C/D ratio measurement in dorsopalmar view of metacarpal bone. Cortical thickness (A & B) and diameter (C) are shown. C/D = $\frac{A+B}{C}$.

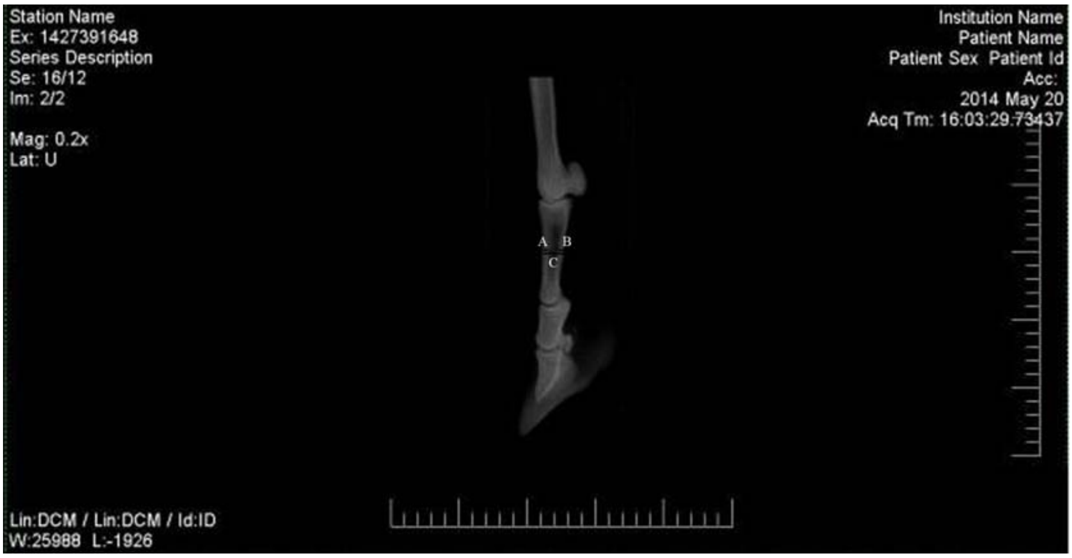

Figure 3- C/D ratio measurement in lateromedial view of proximal phalanx in hindlimb. Cortical thickness (A & B) and diameter (C) of proximal phalanx are shown. C/D in proximal phalanx is $\frac{A+B}{C}$.

The statistical software, SPSS version 9.0 (SPSS Inc., Chicago, IL, USA) was used for analysis. The data were analyzed by independent students T-test. The significance level was set at $P<0.05$. In order to evaluate the significant differences between bones in each limb, One Way Anova was used.

Results

Lateromedial view

The Mean±SE of cortical thickness of radius, metacarpus and proximal phalanx of forelimb in lateromedial view were 1.09±0.03, 1.05±0.03 and

1.11±0.07 respectively. Cortical thickness of tibia, metatarsus and proximal phalanx of hindlimb in lateromedial view were 1.23±0.05, 1.47±0.04 and 0.9±0.03 respectively. Cortical thickness of metatarsus was more than metacarpus significantly (P<0.05) (Table 2), while there was no significant difference between cortical thickness of radius – tibia and proximal phalanx of fore and hind limb in this view (P>0.05) (Table 1).

The Mean±SE of the diameter of radius, metacarpus and proximal phalanx of forelimb in lateromedial view were 2.03±0.09, 1.83±0.03 and 1.74±0.03 respectively. The Mean±SE of diameter of tibia, metatarsus and proximal phalanx of hind limb in this view were 2.21±0.03, 2.26±0.02 and 1.68±0.05, respectively. The difference between those parameters in fore and hind limbs were not significant in lateromedial view (P>0.05) (Tables 1 and 2).

The Mean±SE of C/D ratios of mid radial and mid tibial in lateromedial view were 0.54±0.02 and 0.56±0.01 respevtively. The Mean±SE of C/D ratios of mid metacarpal and mid metatarsal region in this view were 0.58±0.02 and 0.65±0.02 respectively. Also in lateromedial view, the Mean±SE of C/D ratios of mid of the 1st phalanx of forelimb was 0.63±0.04 while it was 0.54±0.03 in hindlimb. There were no significant differences between C/D ratios in any measured regions in lateromedial view (P<0.05). C/D ratio of mid radius and mid tibia also has no significant difference (P>0.05) in lateromedial view. Statistical results showed no significant differences between C/D ratios of mid metacarpus and mid metatarsus and also mid of the 1st phalanx of forelimb and hind limb (P>0.05). All data are presented in tables 1, 2 and 3.

Table 1: Mean of total cortex thickness, bone diameter and C/D index of Radius/Tibia in LM view

Anatomical region	Mid Radius/Tibia		
	Mean±SE of cortex (cm)	Mean±SE of bone diameter (cm)	Mean±SE of C/D index
Radius	1.09±0.03	2.03±0.09	0.54±0.02
Tibia	1.23±0.05	2.21±0.03	0.56±0.01

Table 2: Mean of total cortex thickness, bone diameter and C/D index of metacarpal/metatarsal region in LM view

Anatomical region	Mid Metacarpal/Metatarsal region		
	Mean±SE of cortex (cm)	Mean±SE of bone diameter (cm)	Mean±SE of C/D index
Metacarpus*	1.05±0.03*	1.83±0.03*	0.58±0.02*
Metatarsus*	1.47±0.04*	2.26±0.02*	0.65±0.02*

*The P value of Mean±SE of cortex was 0.005. P value of Mean±SE of C/D was 0.007(P<0.05 was significant).

Table 3: Mean of total cortex thickness, bone diameter and C/D index of 1st phalanx of forelimb/1st phalanx of hindlimb in LM view

Anatomical region	Mid 1st phalanx of forelimb/1st phalanx of hindlimb region		
	Mean±SE of cortex (cm)	Mean±SE of bone diameter (cm)	Mean±SE of C/D index
1st phalanx of forelimb	1.11±0.07*	1.68±0.05	0.54±0.03
1st phalanx of hindlimb	0.9±0.03*	1.68±0.08	0.54±0.05

*The P value of Mean±SE of cortex was 0.005. P value of Mean±SE of C/D was 0.007(P<0.05 was significant).

Dorsopalmar/Dorsoplantar views

The results of dorsopalmar and dorsoplantar radiographic views were listed in the tables 4, 5 and 6. According to these data, the Mean±SE of cortical thickness of radius, metacarpus and proximal phalanx of forelimb in this view were 1.67±0.06, 1.49±0.02 and 1.34±0.05 respectively. There were no significant difference between cortical thickness of radius – tibia, metacarpus - metatarsus and proximal phalanx of fore and hindlimb in this view (P>0.05) (Table 5).
The Mean±SE of the diameter of radius, metacarpus and proximal phalanx of forelimb in this view were 3.07±0.08, 2.48±0.04 and 2.41±0.03 respectively while the Mean±SE of the diameter of tibia, metatarsus and proximal phalanx of hind limb in this view were 3.31±0.05, 2.29±0.06 and 2.45±0.08 respectively. There was no significant difference between the bone diameter in fore and hindlimbs (P>0.05) but the cortex of metacarpus was no significantly thicker than the metatarsus (Table 5).
The Mean±SE of C/D ratios of mid radius and mid tibial regions in dorsocaudal view were 0.55±0.03 and 0.49±0.02 respevtively. The Mean±SE of C/D ratios of mid metacarpal and mid metatarsal regions in the dorsopalmar and dorsoplantar views were 0.6±0.01 and 0.57±0.02 respectively. Also in this view, the Mean±SE of C/D ratios of mid of the 1st phalanx of forelimb and hindlimb were 0.55±0.02 and 0.55±0.04 respectively. There was a significant difference between C/D ratio of mid metacarpus and mid metatarsus (P<0.05) (Table 5).

Table 4- Mean of total cortex thickness, bone diameter and C/D index of Radius/Tibia in DV view

Anatomical region	Mid Radius/Tibia		
	Mean±SE of cortex (cm)	**Mean±SE of bone diameter (cm)**	**Mean±SE of C/D index**
Radius	1.67±0.0.06	3.07±0.08	0.55±0.03
Tibia	1.63±0.05	3.31±0.05	0.49±0.02

Table 5- Mean of total cortex thickness, bone diameter and C/D index of metacarpal/metatarsal region in dorsopalmar / dorsoplantar view

Anatomical region	Mid Metacarpal/Metatarsal region		
	Mean±SE of cortex (cm)	**Mean±SE of bone diameter (cm)**	**Mean±SE of C/D index**
Metacarpus	1.49±0.02	2.48±0.04	0.6±0.01
Metatarsus	1.32±0.06	2.29±0.06	0.57±0.02

*Mean with the same superscripts are significantly differed. The P value of Mean±SE of cortex was 0.04. P value of Mean±SE of C/D was 0.007 (P<0.05 was significant).

Table 6: Mean of total cortex thickness, bone diameter and C/D index of 1st phalanx of fore limb/1st phalanx of hind limb in dorsopalmar / dorsoplantar view

Anatomical region	Mid 1st phalanx of fore limb/1st phalanx of hind limb region		
	Mean±SE of cortex (cm)	**Mean±SE of bone diameter (cm)**	**Mean±SE of C/D index**
1st phalanx of fore limb	1.67±0.05	2.41±0.03	0.55±0.02
1st phalanx of hind limb	1.35±0.12	2.45±0.08	0.55±0.04

Discussion

Bone densitometry is one of the main methods in diagnosis of osteoporosis. The most common techniques in this regard are dual X-ray absorptiometry (DXA), quantitative computed tomography (QCT), and quantitative ultrasound (QUS).[4] This comparison contributes to the diagnosis of osteoporosis, helps in determining future fracture risk, and the need for pharmacologic therapy and fracture prevention programs. It is also useful in evaluating the effectiveness of prior or current therapy.[18] Osteoporosis is associated with an increased risk of fracture.[19] Clinically, the diagnosis of osteoporosis is made in its advanced stages and usually following a bone fracture. As the presenting fracture is associated with an increased risk of subsequent fractures, it is important to diagnose and treat osteoporosis prior to the development of the first fracture.[20] Accurate, precise, and noninvasive skeletal assessment is now possible for early detection of osteoporosis at a preclinical stage.[21]

This study has identified morphometrical variations between cortex, diameter and their C/D ratios in fore and hind limb and also reported some variations between the dorsopalmar/dorsoplantar and LM views in the bones. Hence, if there are specific morphological features that are associated with supporting more weight, then these features should show consistent differences between these different bones. The C/D index was obtained on the basis of the cortical thickness measurement only, because this index is not affected by disturbing factors such as age, sex, weight, height and breed. C/D ratios are very important and practical index that can be used to assess bone health.[4] Bone diseases causing decrease in bone density can be detected in early stages by knowing normal C/D ratios of bones in different animals. Soroori et al. have studied radiographic assessment of bone cortex to bone diameter ratio of manus and pes in camel. They reported significant differences between C/D ratios of manus and pes measured in mid metacarpal/metatarsal region and metacarpal/metatarsal just proximal to its bifurcation ($P<0.05$).[17] In the study by Watson *et al.* (2003), the bone radiographs were measured from the highest point of the proximal extremities to the lowest point of the distal condyles in the Thoroughbred racehorse. The aim of this study was to compare the height of lateral and medial walls of metacarpal bone and assessment the forces on them.[12] In other study, the measurement was taken directly from the bones from the highest point of the proximal extremities to the lowest point of the distal extremities.[22] The aims of this study were to evaluate the diameter of metacarpus and metatarsus and their cortex diameter, correlation of these values and comparison of them in thoracic and pelvic limb of sheep. They suggested the results of present study can help to detect the abnormal diameters in this bones.[23]

In our study, the cortical thickness and diameter of mid radial and metacarpus regions were lesser than mid tibial and metatarsus in lateromedial view respectively (Table 1 and table 2). Also the cortical thickness of proximal phalanx of forelimb was significantly thicker than hind limb ($P<0.05$). It means that cortex of metatarsal bone and proximal phalanx of forelimb bear more load than metacarpus and proximal phalanx of hind limb respectively. Our findings about phalanxes were similar to other same studies in camel but were in contrast of those in manus and pes regions.[17]

Results in dorsopalmar and dorsoplantar views shows that lateral and medial cortexes of metacarpus support more weight than metatarsus but there were no significant differences ($P>0.05$) between Mean of them (Tables 4, 5 and 6). In quadrupeds, the center of gravity is located in the body center of a standing animal and shifts around the center during locomotion.[7] Furthermore, a greater proportion (60%) of the body weight of the horse is borne on the front legs.[24] Additionally, the 3rd metacarpus in the stance phase is primarily loaded in axial compression.[25] However, donkeys similar to the horses may increase in body weight,[26] so there are likely to be the changes in bone morphometry because of the increased load from the increasing weight.[22] According to some studies lateral condyle of the third metacarpal bone and its hyaline cartilage are thicker than medial ones that presumably receive more load per unit area.[27,28,29] The thickness of the hyaline cartilage layer increased when subjects were exposed to an active exercise regimen.[27,28] Also Hartog *et al.* (2009) showed that the equine fetlock carries load on its medial and lateral sides.[30] These are in agree with our results that showed lateromedial cortex of each bone is thicker than dorsopalmar and dorsoplantar one. So obtained results in this study confirm that lateromedial cortex because of its thickness bears more load and support more weight than another one in Miniature donkey. Also during walking, trotting and galloping, the forelimbs bear more weight than the hindlimbs.[31] Eckstein *et al.* (2009) suggested that the increase in the surface area of bone can distribute the load over a wider area and consequently lead to a decrease in the mechanical stress on the surface.[32] It can explain the cause of more cortical thickness of forelimb in DV view than hind limb.

In addition morphometrical studies can help to evaluate the effects of the morphology on factors such as loading on selected parts of bone surfaces. This will create opportunities for further study into the incidence of various types of fractures and pathological lesions as well as identifying differences between breeds and types of equide that have been selected for different purposes. It seems that forelimb in Miniature donkey carries more load than hind limb which is similar to other studies in the horse.[7,24,25]

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چکیده

ارزیابی رادیوگرافی نسبت کورتکس به قطر استخوان های زند زبرین، درشت نی، قلم دست، قلم پا و بند اول انگشت دست به بند اول انگشت پا در الاغ مینیاتوری

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هدف- هدف از این مطالعه، اندازه گیری نسبت کورتکس به قطر در استخوان های زندزبرین/درشت نی، قلم دست/قلم پا و بند اول انگشت اندام حرکتی قدامی/خلفی به منظور ارائه یک راهنمای تشخیصی در بیماری های متابولیک و تغذیه ای در الاغ مینیاتوری بود.

طرح مطالعه- مطالعه تجربی

حیوانات- هشت الاغ مینیاتوری بالغ

روش کار- رادیوگراف هایی که از نماهای جانبی – میانی، پشتی - کف دستی و پشتی – کف پایی از اندام حرکتی قدامی و خلفی هشت الاغ مینیاتوری بدست آمده بود مطالعه گردید. ضخامت کورتکس، قطر و نسبت کورتکس به قطر (C/D) وسط استخوان های زند زبرین به درشت نی، وسط قلم دست به قلم پا، و وسط بند اول انگشت اندام حرکتی قدامی به خلفی اندازه گیری شد. اطلاعات بدست آمده آنالیز گردید و میانگین، انحراف معیار و معناداری آنها بررسی شد.

نتایج- نسبت کورتکس به قطر میانه های زندزبرین، قلم دست و بند اول انگشت قدامی در نمای جانبی – میانی به ترتیب ۰/۵۴±۰/۰۲، ۰/۵۸±۰/۰۲ و ۰/۵۴±۰۳/۰ بود. نسبت کورتکس به قطر میانه درشت نی، میانه قلم پا و میانه بند اول انگشت پا در نمای جانبی – میانی به ترتیب ۰/۵۶±۰/۰۵، ۰/۶۵±۰/۰۲ و ۰/۵۴±۰/۰۳ بود. نسبت کورتکس به قطر میانه زند زبرین، میانه قلم دست و میانه بند اول اندام حرکتی قدامی در نمای پشتی – کف دستی به ترتیب ۰/۵۵±۰/۰۳، ۰/۶±۰/۰۱ و ۰/۵۵±۰/۰۲ بود. این نسبت در میانه درشت نی، میانه قلم پا و میانه بند اول انگشت در اندام حرکتی خلفی در نمای پشتی – شکمی و پشتی – کف پایی به ترتیب ۰/۴۹±۰/۰۲، ۰/۵۷±۰/۰۲ و ۰/۵۵±۰/۰۴ بود.

نتیجه‌گیری و کاربرد بالینی- این مطالعه نشان داد که اختلاف معناداری بین نسبت کورتکس به قطر در هیچ ناحیه ای وجود ندارد. کورتکس و قطر در نمای جانبی – میانی بین قلم دست با قلم پا و ضخامت کورتکس بند اول انگشت اندام حرکتی قدامی در مقایسه با اندام حرکتی خلفی، اختلاف معنادار داشتند.

کلمات کلیدی- رادیوگرافی، نسبت کورتکس به قطر استخوان، اندام حرکتی قدامی، اندام حرکتی خلفی، الاغ مینیاتوری.