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Arthro-Biomechanical Investigation of the Tarsal Joint of One-Humped Camel (*Camelus dromedarius*) during gait: Forensic Biomechanics Evidence

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ABSTRACT

It is expected that dromedary camel's tarsus plays a crucial role in survivals in the arid and semiarid regions. These regions are open and the dromedary camel is tall with long legs. Thus, databases of biomechanical variables are needed to investigate the changes of velocity, displacement, angular changes as well as anatomical consideration of tarsal joint during walking and stance phase. Nine healthy camels of three different sizes and ages were selected for gait analysis using motion track program. Moreover, five tarsal joints cadavers obtained for 3D reconstruction computed tomography. The present study stated that, tarsal joint is a hinge biaxial joint, primarily allowing flexion, extension and small amount of rotation and gliding movement. The gait analysis during walking revealed some data of hind limb velocity, angular change and displacement of tarsal joint. Different sizes of camel had no significant effect on average and minimum value of velocity of hind limb during walking. Medium sized camel showed higher degree of extension of tarsal joint than small and large one. Medium and large camel showed significant higher vertical (p=0.01) and horizontal (p=0.05) displacement of right tarsal joint than small camel during walking. We anticipate our findings can be a useful tool in lameness investigation to discriminate between the normal and diseased gait as expecting the nature of the inhabitant environment as well as add promising evidence in the field of forensic biomechanics to avoid legal violations in racing camels.

1. INTRODUCTION

The camel plays an important socio-economic role in the life as for milk and meat production as well as for draught and riding purposes (Khan et al., 2003; Farah et al., 2004). Moreover, camel reared for fleece production (Hoffman, 2006) and recently, for racing and beauty shows. Camels have good locomotor apparatus that enables them to be excellent racing animals, well adapted to travel fast on sandy soil (Smuts and Bezuidenhout, 1987; Janis et al., 2002; Khan *et al*., 2003; Badawy, 2011). A gait can be defined as a complex and firmly co-ordinated rhythmic and automatic movement of the limbs and the entire body of the animal which result in the production of progressive movements as symmetry (walk, pace, trot) or asymmetry (canter, gallop) of the limb movement sequence (Barrey, 1999). Similar to giraffes, camels move both legs together on each side of their body during walking (Desert U. S. A, 2013). The tarsus is an anatomically compound joint with several articulations, tendons and ligaments

(Smuts and Bezuidenhout, 1987) and is considered a basic source of lameness in hind limb (Ehlert et al., 2011; Raes et al., 2011) due to nature of camel laying behaviour. The lameness of camel is differing from bovine and equines, due to its special anatomy, biomechanics, geoclimatic adaptation and use (Al-Ani, 2004; Gahlot, 2007). Moreover, Lameness in racing camels is also considered to be a major complicated economic problem and need more advancing technique to be detected and diagnosed. Therefore biomechanics diagnosis of camel leg can be a challenge especially of tarsus, so the requirement of additional imaging modalities which may be useful in defining the anatomic origin of lameness that localized at the tarsus (Van der Vekens et al., 2011). Biomechanically indicate that locomotion involves moving all the body and limb segments in rhythmic and automatic patterns which define the various gaits. As with any other body system, movement can be explained by mechanical laws (Barrey, 1999). Furthermore, the biomechanics is very important for detecting subclinical abnormalities and automatic lameness detection, (Maertens et al., 2008). Objective biomechanical techniques could provide a valuable method to define the gait problems in commercial farming system (Pluk et al., 2012; van Nuffel et al., 2009). This in turn would improve the ability of breeders/farmers to indirectly breed selection or breed replacement (Bienert, and Stadler, 2006). Besides, three-dimensional give good anatomic orientation and provide more sensitive detection and characterization of joint disease extension (Tucker and Sande, 2001; Bienert and Stadler, 2006). Some researchers have been studied anatomical structures of camel bones (Soroori et al., 2007), tendons (Soroori et al., 2011) and digits foot pad (Badawy, 2011) of the forelimb in one-humped camel by means different methods but until now the a reference for the normal biomechanics study of tarsal dromedary camel is lesser and also is rare and has not been reported. So the goal of the present work was to parameterize normal detailed kinematics biomechanical study with anatomical reference for the dromedary camel tarsus that act as basic references to any pathological and abnormal gait.

2. MATERIAL AND METHODS

This study was carried out to investigate biomechanically and anatomically changes of tarsal joint of one humped camels during locomotion.

2.1. Three Dimension reconstruction Computed Tomography examination

Five tarsal joints cadavers obtained from slaughtered apparently healthy dromedary camels of both sex (3 males and 2 females); the average ages for all animals were a young animals (2.3 ± 0.5 years old). All used for 3D reconstruction computed tomography (CT). Using a 64 detector row CT scanner (Somatom Sensation, Siemens Medical Solutions, Forcheim, Germany), at 130 kVp and 160 mAs. All CT images were reformatted in dorsal and sagittal planes by use of software (Syngo CT 2006G, ICS VB28B, Siemens, Munich, Germany).

2.2. **Biomechanical analysis:**

Camels of both sexes (6 males and 3 females) were obtained from educational farm of faculty of Veterinary medicine, University of Sadat City. All animal-management procedures were carried out according to the regulations of Institutional Animal Care and Use Committee (IACUC). Nine healthy camels of three different sizes were selected for biomechanical gait analysis. Average camel's weights and ages were (166.66 Kg – 3.1 years old; 400 Kg – 4.1 years old; and 633.33 Kg – 5.2 years old) and average camel's heights were (165, 193 and 216 cm) for small, medium and large size camel respectively. Each camel was observed during walking by using video camera (Sony, VHS HI 8 mm, Japan) for 5 minute. All videos were stored on a computer (IBM, 64 Mp and hardware 80 Gp). Films were processed by using motion track program (No 665/5) that registered at 2001 with measurement unite (0.50m×0.50m ×0.50m) for analysis of camel gait. The motion track program can analyze the normal gait through different frame as well as process each movement of each part of body and convert to various data. Therefore, we collected some data as velocity that defined as the times when the individual hind limb either right or left contacted and left the ground (Peham et al., 1999), angular change (value of flexion and extension degree of tarsal joint) and horizontal and vertical displacement of the tarsal joint from the zero point during walking

2.3. Statistical analysis

All data were analyzed statistically using IBM SPSS statistics (version 22). Differences between three sizes of camels were analyzed by ANOVA test**.**

3. RESULTS

3.1. Three Dimension reconstruction Computed Tomography:

Camel tarsal joint was a compound joint in which the bones were arranged into three rows with several articulations between them (tarsocrural or tabiotarsal, talocalcaneal, intratarsal, and tarsometatarsal joints) (Fig. 1). All bone structures, including calcaneus, point of hock, talus with its trochlear ridges in first row; central tarsal and fourth tarsal bones in the second row; first tarsal and fused second and third tarsal bones in the last row (Fig. 2). In the 3D CT image, the tarsal bones had smooth outline as well as the malleolar bone, the intermediate ridge of the tibia, trochlear ridges of the talus, inter-tarsal bones, moreover the articular cartilage could be assessed thoroughly (Fig. 2). Using the three dimension reconstruction computed tomography, the irregular shape of all bone structures were examined (Fig. 1, 2).

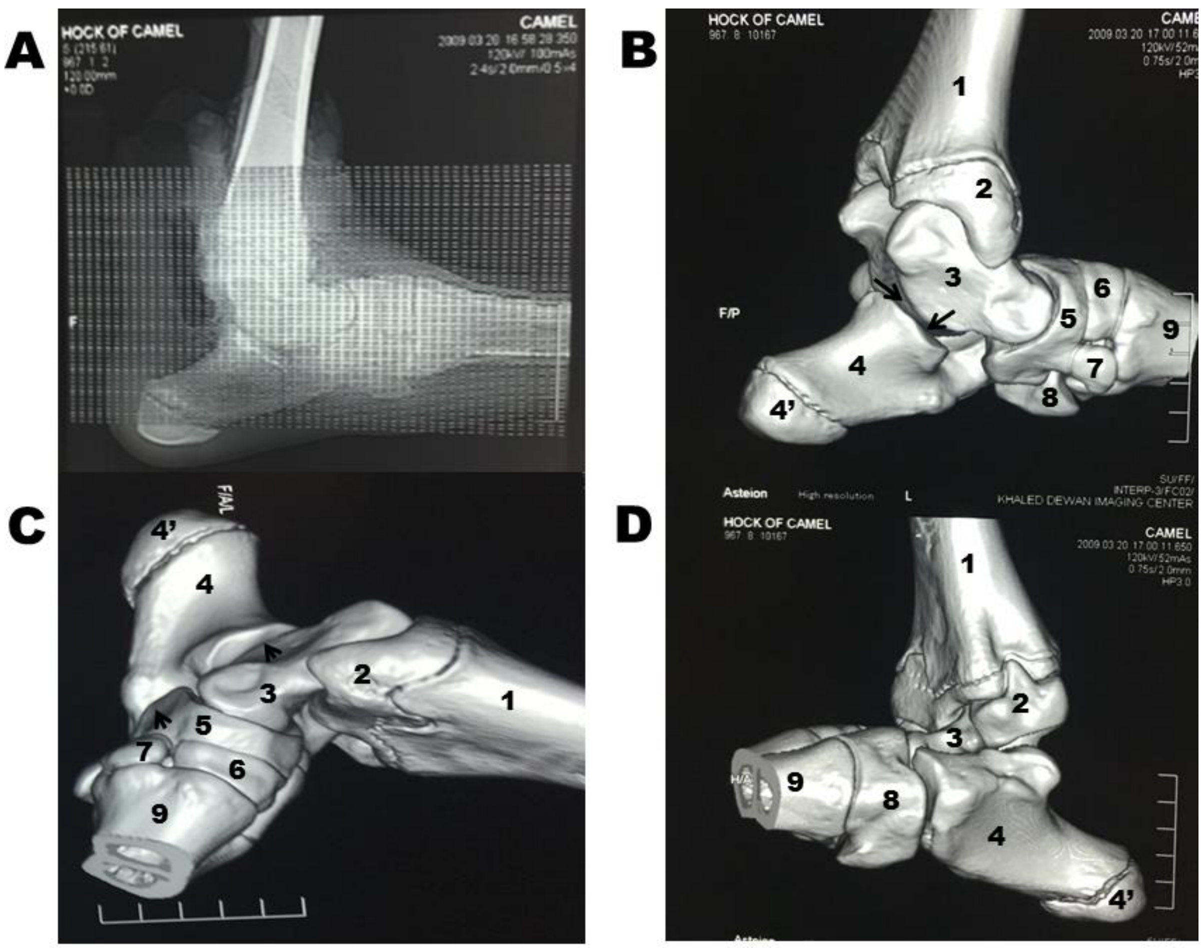

Figure (1): 3D CT images of tarsal region in young dromedary camels (2.3 years old) showing; A: scout film showing the interval levels of taken images, 2 mm intervals between each image. B and C: showing medial view. D showing lateral view.
1: Tibia **2:** Malleolar bone **3:** Talus **4:** Calcaneus **4':** Tuber of calcaneus **5:** Central tarsal bone **6:** Fused second and third tarsal bone **7:** First tarsal bone **8:** Fourth tarsal bone
9: Metatarsal bone (3rd at the medial view, 4th at the lateral view)

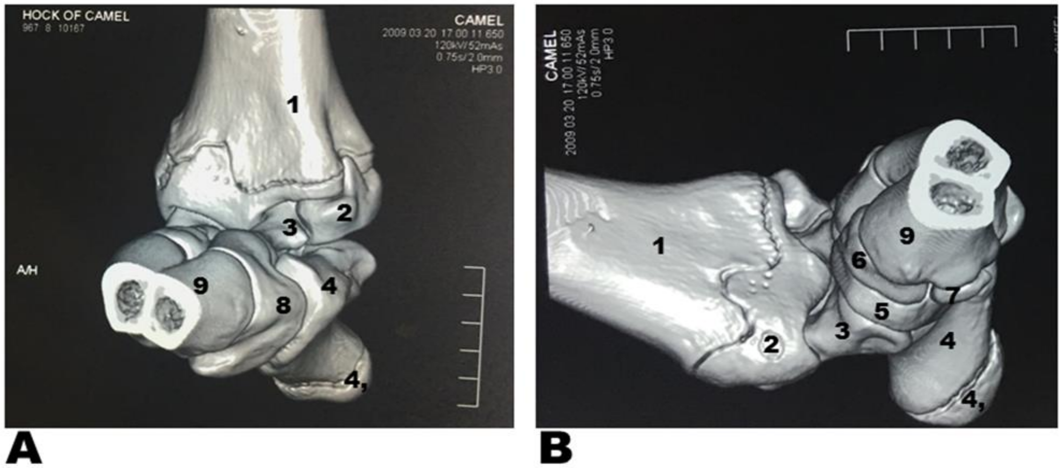

Figure (2): 3D CT images of tarsal region in young dromedary camels (2.3 years old) showing A: Lateral view. B: Medial view. **1:** Tibia **2:** Malleolar bone **3:** Talus **4:** Calcaneus **4':** Tuber of calcaneus **5:** Central tarsal bone **6:** Fused second and third tarsal bone **7:** First tarsal bone **8:** Fourth tarsal bone **9:** Metatarsal bone (3rd at the medial view, 4th at the lateral view)

3.2. Biomechanical analysis

Data summarized in Table (1) denoted that different sizes of camels had no significant effect on average and minimum values of velocity of hind limb during walking. On the other hand maximum values of hind limb velocity of medium and large sized camel were significantly higher than small size camel either right hind limb (5.84±0.43, 6.61±0.58 and 4.15±0.98 m/sec respectively) or left hind limb (6.09±0.86, 8.14±1.16 and 5.38±0.69 m/sec respectively). The degree of angular change of tarsal joint significantly differed between different sized camels as illustrated in Figures (4) and (5). Medium sized camels showed higher degree of extension in both right and left tarsal joint than small and large sized one. As average of angular change of right tarsal joint for each small, medium and large camels (135.07, 141.24 and 139.37°) respectively. The least value of angular change in right tarsal joint of small sized camels when compared with medium and large sized ones (102.85, 105.01and 114.40°) while the highest degree of extension was observed in right tarsal joint of medium and large sized camels in comparison to small sized ones (155.73, 152.72 and 151.19°, respectively, P=0.05). Besides, extension degree of left tarsal joint for small, medium and large camel equal (140.74, 142.33 and 137.20°) respectively. As the least degree of left tarsal extension (116.48, 105.05 and 117.60°) and highest degree (157.66, 160.44 and 151.11°) were observed in small camels in comparison to medium and large sized one. Data summarized in Figures (6, 7, 8) wave changing of angle in tarsal joint either left or right side of different sizes camels that showed interesting findings where tarsal joint did not reach to hyperextension degree (more than 180°) during gait. Tarsal joint displacement either horizontal or vertical was differed significantly between different sizes of camels during walking as shown in Table (2). Medium and large camels showed significant higher horizontal (p=0.05) and vertical (p=0.01) displacement of right tarsal joint than small camels during gait. Furthermore, horizontal displacement of left tarsal joint of medium camels significant (p=0.05) differed than small ones.

Table (1): Velocity of hind limb of different sized camels (m/sec) (means ± SE)

Velocity (m/sec)	**Right hind limb**			P value
	Camel			
	Small	Medium	Large	
Minimum	0.35±0.12	0.61±0.18	0.43±0.02	0.21
Maximum	4.15±0.98[b]	5.84±0.43[a]	6.61±0.58[a]	0.01
Average	3.22±0.21	3.28±0.16	3.40±0.20	0.17
	Left hind limb			
Minimum	0.29±0.05	0.29±0.04	0.27±0.004	0.27
Maximum	5.38±0.69[b]	6.09±0.86[a]	8.14±1.16[a]	0.03
Average	3.43±0.22	3.21±0.26	3.55±0.41	0.77

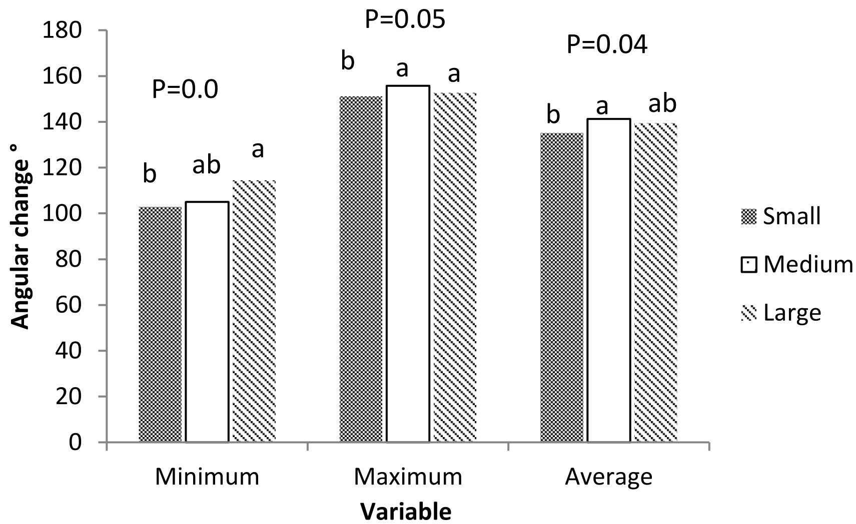

Figure (3): Angular change of right tarsal joint of different sized camels (°) (mean ± SE)

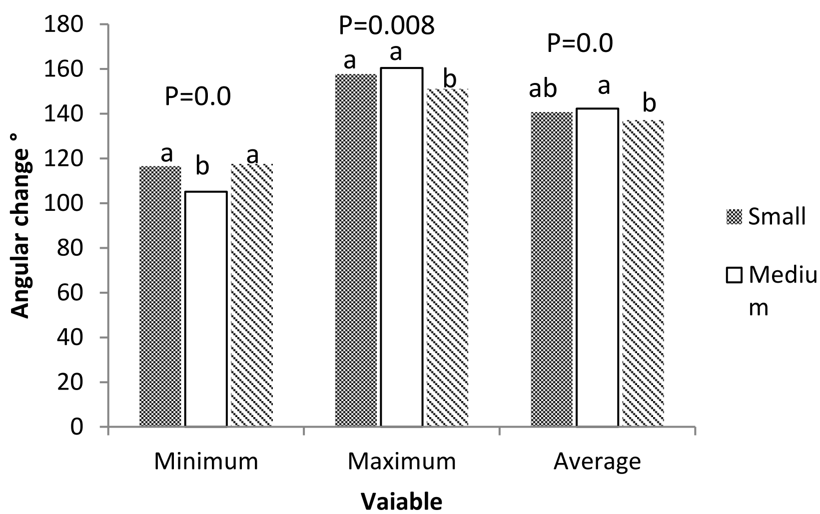

Figure (4): Angular change of left tarsal joint of different sized camels (°) (mean ± SE)

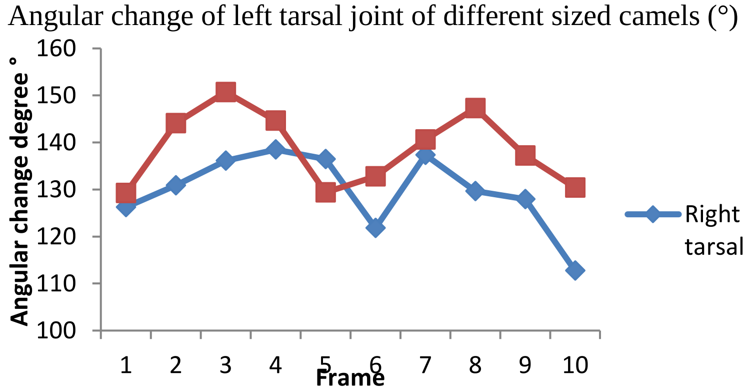

Figure (5): Wave changing of angle in tarsal joint (left and right) of the Small Camel (°)

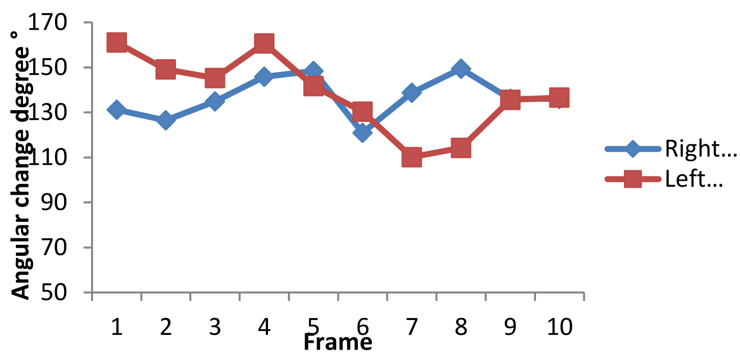

Figure (6): Wave changing of angle in tarsal joint (left and right) of the medium camel (°)

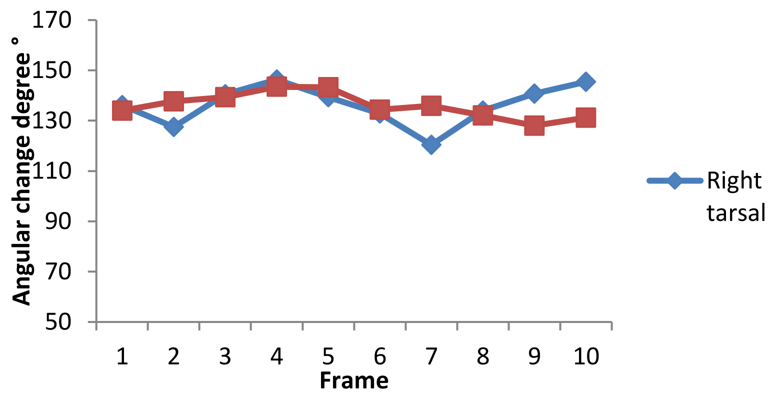

Figure (7): Wave changing of angle in tarsal joint (left and right) of the large Camel (°)

Table (2): The displacement of the tarsal joint of camel during normal gait (m) (mean ± SE)

Items	Right tarsal joint			P value
	Camel			
	Small	Medium	Large	
X range	0.99±0.33[b]	1.80±0.25[a]	1.68±0.007[a]	0.05
Y range	0.14±0.02[b]	0.20±0.01[a]	0.23±0.02[a]	0.01
	Left tarsal joint			
X range	1.20±0.17[b]	1.70±0.18[a]	1.56±0.11[ab]	0.05
Y range	0.20±0.01	0.22±0.01	0.25±0.01	0.16

X and Y means horizontal and vertical distance of tarsal joint motion respectively

4. DISCUUSION

4.1. Three Dimension reconstruction Computed Tomography:

The tarsal joint is considered as a key joint in determining the performance and speed ability of animal and sustains body weight during standing and sitting position, so that it is highly susceptible to several orthopedic problems (Clegg, 2003), these problems are seem to be increased as camel lives in desert environment and adapted to uneven surface, so the correct examination of joint problems like three dimensional analysis is very important to create good animal management (Bienert and Stadler, 2006) . The tarsal joint is hinge biaxial joint, primarily allowing flexion and extension and small amount of rotation and gliding movement, it moves around two axis, transvers axis (flexion and extension) and vertical axis that includes (adduction or inversion ,internal rotation) and (abduction or evertion ,external rotation). Because of absence muscles attach directly to the talus, no pure flexion or extension. So the gliding movement between the talus cranially and the calcaneus caudally is predominate, so a major portion of abduction and adduction occurs at that articulation as well as in the tarso-metatarsal joints. Static anatomical structures of camel tarsal joint as bony parts is similar to that observed by (Hagag et al., 2013) including tibial cochlea, calcaneus, talus with its trochlear ridges, central tarsal bone, fourth tarsal bone, first tarsal bone, fused second and third tarsal bone. On the other hands, ligaments and tendons are similar findings which reported by in camel (Hagag et al., 2013); in equine (Van der perren et al., 2008; Raes et al., 2011; Van der Vekens et al., 2011) and canine (Gielen et al., 2001). The ideal and most economic structure, which has anti-concussion function of tarsal bones are short bones with specific hollow trabecular system for sustains the high forces exerted upon the bone and decrease friction, on the other hands, the calcaneus bone called the point of hock, act as a leverage arm to the muscles which extend on the tarsal joint to provide propulsion during the locomotion (Getty et al., 1975). The ligaments of the tarsal joint that connect the bone tarsus together included short and long parts of the medial and lateral collateral ligaments, inter-osseous ligaments and the medial and lateral limbs of the long plantar ligament that is similar to (Hagag et al., 2013; Smuts and Bezuidenhout, 1987). Moreover, tarsal joint has the largest surface area (Carl et al., 1994) as it has several articulations, tibio-tarsal articulation, inter tarsal articulation and tarso-metatarsal articulation, and so a various imaging modalities are required to sucssesfully identify these lesions especially in complex joints such as the tarsus. The bones are complex, dynamic organs that constantly change to adopt the demands which place on them, (Martini et al., 2001); as there are some factor affecting the joint mobility as configurance and fittness of articular surface, strength and thickness of fibrous capsule as well as accessory ligaments of the joints, the muscles and tendons are the most important factors in the stabilization of the joints due to their contraction keep articular surface in firm contact and muscles work as contractile ligaments and are capable of modifying the action according to the needs of the movements. When the muscle is paralyzed, the joint become flaccid and ligaments are relaxed or shortened allowing undesirable mobility of the joint, and when muscle is off action, a little force may leads to dislocation of joint; that is similar to observed by (Edinger 2010). On the other hand, (Schamhardt et al., 1989) suggested other factores as reduction of blood supply, feeding, racing and congenital abnormaities that cause of bony spavin, degenerative disease that develops predominantly at intertarsal joints.

4.2. Biomechanical analysis:

The economic consequences of lameness needs great effort now to be quantification and prevention as well as to improve breeding and reduce the costs of training, early performance evaluation tests as biomechanics analysis should be applied which provide many descriptive parameters of joint mobility, such as the angle variations during the stride cycle. These types of analyses quantitatively describe the clinical signs and considered as specific applications that can be used under field conditions (Barrey, 1999). The kinematic and dynamic information's about the tarsal joint was the results of environmental and natural evolutions that gradually led to the development of enhanced locomotors properties as recorded by Cano et al., (2001), who said that, the dimensional analysis of the tarsal joint angle provided an important information for studying kinematic trot characteristic of the animal by means of angular range motion which determined during gait. The results of current study revealed that changes of degree of tarsal joint angle from small to large camels were observed during walking gait. Holmström et al., (1990) reported that tarsal angles in younger (4-year-old) horses in the range of 145–169° with smaller angles being found by using a combination of measurements from the live horse and photographs. However, Marks, (2000) categorized an angle of tarsus of horse was less than 150° as angulated and an angle greater than 170° as straight. It was suggested that these differences of angular degree of tarsal joint due to different criteria were used to measure these angles and difference of species. During normal gait of camel angular degree of tarsal joint not reach to hyperextension degree (more 180°) that may regarded to anatomical structure of tarsal joint as no muscles attach directly to the talus bone of tarsus that showed previously at CT examination and this indicate movement of tarsal joint was no pure flexion or extension, but gliding movement. It was reported that medium camel showed higher degree of flexion and extension and displacement of right tarsal joint than small one. These results were disagreement with (Faria et al., 2014) who studied kinematic analysis of forelimb and hind limb joints of two groups of clinically healthy sheep of different age 12 month and 5 years and reported that within each group, younger sheep showed higher flexion with minimum angular displacement of tarsal joint than older sheep. These differences may be attributed to joint changes that occur during growth as joint angles become more stretched (Back et al., 1995 a1). However flexion and extension degree and angular displacement of tarsal joint were significant differed between different sizes of camels the velocity of hind limb either right or left did not differed. As average of velocity equal

(3.22±0.21, 3.28±0.16 and 3.40±0.20 m/sec) for right hind limb and (3.43±0.22, 3.21±0.26 and 3.55±0.41 m/sec) for left hind limb for each small, medium and large camel respectively. Gnagey et al., (2006) who compared tarsal kinematics and kinetics in horses with large tarsal angle (>165.5°), intermediate tarsal angle (155.5° to 165.5°), and small tarsal angles (<155.5°) reported that speeds for each group (3.15 ± 0.03 m/sec in horses with small tarsal angles, 3.18 ± 0.05 m/sec for horses with intermediate tarsal angles, 3.14 ± 0.07 m/sec in horses with large tarsal angles). Speed did not differ significantly between groups. These results might regard to medium sized camels with large tarsal angle degree may reduce the plantar ligament desmitis that stabilize the calcaneus in opposition to tension applied to the tuber calcanei by the extensor musculature during walking. These results supported (Stashak, 1987) who reported horses with large tarsal angles may reduce the plantar ligament desmitis and, perhaps, offer some support to the suggestion that a small tarsal angle affects to plantar ligament desmitis. Additionally, joints assist in shock absorption through compression of the joint angles which involves flexion of the tarsal joint (Back et al., 1995 a2). Holmström (2000) reported a higher incidence of lameness in horses with small tarsal angles due to the more closed position during weight bearing which may be related to a compression of the dorsal surface of the joint. Beside Gnagey et al., (2006) reported that increasing tarsal angles of horse more than 165.5° are less effective for shock absorption, which may predispose to the development of degenerative joint disease. Therefore, the results of current study of tarsal joint of different sizes camels could be used as a reference for early prediction and detection of lameness of camels.

5. CONCLUSIONS

It is concluded that medium sized camels showed higher degree of tarsal joint extension and displacement during normal gait with constant velocity in comparison to small and large sized ones. This regarded to anatomical nature of tarsal joint as differences of tarsal bone shape with tendons and ligaments support. Beside, we decided that medium camels were high gait quality and better shock absorption during walking and might less development of degenerative joint disease and lameness. Therefore, we recommended decreasing the loads and hard work on small and large size camels. Our findings can be a useful tool in lameness investigation to discriminate between the normal and diseased gait as expecting the nature of the inhabitant environment as well as add promising evidence in the field of forensic biomechanics to avoid legal violations in racing camels.

6. REFERENCES

Al-Ani FK. Camels: Management and Diseases. First Edition. Dar Ammar Book Publisher; 2004, P. 30-45.

Back, W., Schamhardt, H. C., Hartman, W., Bruin, G., Barneveld, A. 1995 a1. Predictive Value of Foal Kinematics for the Locomotor Performance of Adult Horses. Res. Vet. Sci. 59:64–69.

Back, W., Schamhardt, H., Savelberg, H., Van Den Bogert, A., Brulin, G. 1995 a2. How The Horse Moves: 2. Significance of Graphical Representations of Equine Hind Limb Kinematics. Equine Vet. J. 27(1): 39-45.

Badawy, A. M. 2011. Computed Tomographic Anatomy of the Fore-foot of the One Humped Camel (*Camelus dromedarius*). Glob. Vet. 6: 417-423.

Barrey, E. 1999. The Methods, Applications and Limitations of Gait Analysis in Horses. Vet. J. 157: 7–22

Bienert, A., Stadler, P. 2006. Computed Tomographic Examination of the Locomotor Apparatus of Horses – A Review. Pferdeheilk 22: 218–222.

Braim, A. E., Bell, R. J., Textor, J. A., Lo, W. Y., Puchalski, S. M., Galuppo, L. D. 2010. Computed Tomography of the Proximal Metatarsal and Concurrent Third Tarsal Bone Fracture in a Thoroughbred Race Horse. Equ. Vet. Edu. 22: 290–295.

Cano, M. R., Vivo, J., Morales, J. L., Galisteo, A. M. 2001. Kinematic Characteristic of Andalusian, Arabian and Anglo-Arabian Horses: A Comparative Study. Vet. Sci. 71: 147-153.

Clegg, P. 2003. Differential Diagnosis of a Swollen Hock in the Horse. In Pract. 25: 328-341.

Desert USA. Camelus Dromedary Newsletter on the Desert Environment Desert USA.com and Digital West Media incorporated. 2013.

Dik, K. J. 1993. Ultrasonography of the equine tarsus. Vet. Radiol. Ultra. 34: 36–43.

Edinger, J. 2010. Significance of Ultrasonographic Examinations of Joints. Pferdeheilkunde. 26: 353-359.

Ehlert, A., Ferguson, J., Gerlach, K. 2011. Magnetic Resonance Imaging and Cross Sectional Anatomy of the Normal Bovine Tarsus. Anat. Histol. Embryol. 40: 234–240.

Farah Z. Abdulkadir O. Abdurahman SH. 2004. Milk and Meat from the Camel: handbook on products and processing. Hochschuleverlag AG ander ETH Zürich. 15-28.

Faria, L. G., Rahal, S. C., Agostinho, F. S., Minto, B. W., Matsubara, L. M., Kano, W. T., Castilho, M. S., Mesquita, L. R. 2014. Kinematic Analysis of Forelimb and Hind Limb Joints in Clinically Healthy Sheep. BMC Vet. Res. 10:294.

Gahlot TK. Proceedings of the International Camel Conference "Recent Trends in Camelids Research and Future Strategies for Saving Camels", Rajasthan, India 16-17 February: 2007: P. 158-165.

Getty R. Anatomy of Domestic Animals. 5th Edition W.B. Saunders Co; Philadelphia, London, Toronto. 1975: P. 296-316.

Hagag, U., Brehm, W., Ramadan, R. O., Al Mubarak, A., El Nahas, A., Gerlach, K. 2013. Computed Tomography and Cross-sectional Anatomy of the Normal Dromedary Camel Tarsus (One Humped Camel). Anat. Histol. Embryol. 42: 266–274

Holmström, M., Magnusson, L. E., Philipsson, J. 1990. Variation in Conformation of Swedish Warm Blood Horses and Conformational Characteristics of Elite Sport Horses. Equ. Vet. J. 22: 186-193.

Holmström M. How Do We Recognize Elite Show Jumpers? In: Proceedings Conference Equine Sport Medical Science. Ed: A. Lindner. 2000: P. 45-56.

Hundson, L. C., Cauzinille, I., Kornegay, J. N., Tompkins, M. B. 1995. Magnetic Resonance Imaging of the Normal Feline Brain. Vet. Radio. Ultra. 36: 267-275.

Janis, C. M., Theodor, J. M., Biosvert, B. 2002. Locomotor Evaluation in Camels Revisited: A Quantitative Analysis of Pedal Anatomy and the Acquisition of the Pacing Gait. J. Verte. Paleontol. 22(1): 110-121.

Khan BB. Iqbal A. Riaz M. Production and management of camels. Part III, University of agriculture, Faisalabad 2003: P.1-20.

Marks, D. 2000. Conformation and Soundness. Proc. Am. Ass. Equ. Pract. 46: 39-45.

Martens, I., Hoppe, B., Stadler, P. 2008. Motion Pattern of the Forelimbs in Horses with Irregular Conformation: A Computer Based kinematographic analysis, Pferdeheilkunde 748-760.

Martini, F. H., Wiliam, C. O., Claire, W., KathleenWelch, M. D., Ralph, T. Fundamentals of Anatomy and physiology. 5th Edition, Prentice-Hall, Inc. Upper Saddle River, New Jersey, USA. 2001.

Nomina Anatomica Veterinaria. Prepared by the international Committee on Veterinary Gross Anatomical Nomenclature (I.C.V.G.A.N) and authorized by the General Assembly of the world Association of Veterinary Anatomists (W.A.V.A.), Knoxville, TN (USA). 5th edition. Published by the Editorial Committee, Hannover, Columbia, Gent, Sapporo, 2005.

Park, R. D., Nelson, T. R., Hoopes, J. 1987. Magnetic Resonance Imaging of the Normal Equine Digit and Metacarpophalangeal Joint. Vet Radiol. 28:105-16.

Peham, C., Scheidl, M., Licka, T. 1999. Limb Locomotionspeed Distribution Analysis as A New Method for Stance Phase Detection. J. Biomech. 32, 1119–1124.

Pluk, A., Bahr, C., Poursaberi, A., Maertens, W., Van Nuffel, A., Berckmans D. 2012 Automatic Measurement of Touch and Release Angles of the Fetlock Joint for Lameness Detection in Dairy Cattle Using Vision Techniques. J. Dairy Sci. 95: 1738-1748.

Puchalski, S. M. 2007. Computed Tomography in Equine Practice. Equ. Vet. Edu. 19:207-209.

Raes, E. V., Bergman, E. H., Vanderperren, H. K., Van der Vekens, E., Saunders, J. H. 2011. Comparison of Cross-Sectional Anatomy and Computed Tomography of the Tarsus in Horses. Am. J. Vet. Res. 72: 1209–1221.

Schamhardt, H. C., Hartman, W., Lammertinik, A. 1989. Forces Loading the Tarsal Joint in the Hind Limb of the Horses, Determind from in Vivo Strain Measurments of the Third Metatarsal Bone. Am. J. Vet. Res. 50(5): 728-733.

Sisson S. Ruminant Osteology. In: Getty R. (Ed.). Sisson and Grossman's the Anatomy of the domestic animals. 5th ed. Philadelphia, W. B. Saunders, 1975.

Skerry, T. M., Lanyon, L. E. 1995. Interuption of Disus by Short Duration Walking Exercise Does not Prevent Bone Loss in the Sheep Calcaneus. Bone. 16: 269-274.

Smuts MS, Bezuidenhout AJ. Anatomy of the dromedary. Oxford, Clarendon Press; 1st Ed: Pp. 20-88. 1987

Soroori, S., Masoudifard, M., Vajhi, A. R., Rostami, A., Salimi, M. 2011. Ultrasonography Study of Tendons and Ligaments of Metacarpal Region in the Camel (*Camelus dromedarius*). Iran J. Vet. Res. 5: 85-88.

Soroori, S., Veshkini, A., Dehghan, M., Farhadian, O. 2007. Radiodraphic Assessment of Bone Cortex to Bone Diameter Ratio of Manus and Pes in Camel. Iranian j. of vet. Sur. (IJVS) 2: 7-12.

Stashak TS. Lameness. In: Adams' Lameness in Horses, 4th edn., Ed: T.S. Stashak, Lea and Febiger. Philadelphia. 1987: P. 695-718.

Taylor, D. D., Hood, D. M., Potter, G. D., Hogan, H. A., Honnas, C. M. 2005. Evaluation of Displacement of the Digital Cushion in Response to Vertical Loading. A Review of equine in equine forelimbs. Am. J. Vet. Res. 66:623-629.

Tomlinson, J. E., Redding, W. R., Berry, C., Smallwood, J. E. 2003 Computed Tomographic Anatomy of the Equine Tarsus. Vet Radiol Ultras. 44:174-8.

Tucker, R. L., Sande, R. D. 2001. Computed tomography and magnetic resonance imaging of equine musculoskeletal conditions. Veterinary Clinics of North America: Equ. Pract. 17: 145-157.

Van Nuffel, A., Sprenger, M., Tuyttens, F. M., Maertens, W. 2009. Cow Gait Scores and Kinematic Gait Data: Can people see gait irregularities?', Animal Wel.18: 433-439.

Vanderperren, K., Raes, E., Van Bree, H., Saunders, J. H., 2009. Diagnostic Imaging of the Equine Tarsal Region Using Radiography and Ultrasonography. Part 2: Bony disorders. Vet J. 179:188-96.

Wilson, D. E., Reeder, D. M. Mammal Species of the World. 3rd ed. USA: Smithsonian Institution Press, Washington; 2005.