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Brief communication

Clubfoot and its implications for the locomotion of a medieval skeleton from Estremoz, Portugal

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A R T I C L E I N F O

Keywords:
Congenital anomaly
Talipes varus
Foot deformity
Degenerative changes

A B S T R A C T

Objective: This study describes foot bone anomalies and the degenerative changes associated with locomotion adaptations.
Materials: An adult male (approximately 29–46 years old) from Estremoz, Portugal (13th–15th century).
Methods: The skeletal anomalies observed in this skeleton were described and measurements were compared between both sides of the individual and with the mean of the adult males from the same collection.
Results: The most anomalous bones are the right medial cuneiform and metatarsals. Degenerative changes are more severe on the left lower limb and right upper limb.
Conclusions: This skeleton represents a unilateral case of talipes varus of the right foot, with the metatarsals being more affected while previously published cases show more severe anomalies of the hindfoot. The degenerative changes observed in the skeleton suggest that both legs and arms, aided by crutches, were used for locomotion.
Significance: This case shows that club foot skeletal anomalies are variable and the pattern of bony changes throughout the body can reveal locomotion adaptations.
Limitations: The possibility of a genetic cause cannot be assessed due to the absence of paleogenomic data.
Suggestions for further research: Since the anomalies found in this case are different than those previously published, we recommend care when analysing foot bones.

1. Introduction

The prevalence of clubfoot varies across ethnic populations, varying from 0.39 to 7 cases per 1000 live births (e.g. Ching et al., 1969; Chapman et al., 2000; Beals, 1978). In Portugal, between 2006 and 2012, the annual incidence of clubfoot in Coimbra varied between 0.87 and 2.58 cases per 1000 live births (Vale, 2014). There is strong evidence for a genetic basis for clubfoot (Wynne-Davies, 1972; Pagnotta et al., 2011; Engell et al., 2014; Kruse et al., 2008) but factors such as maternal age, parity and education are also significantly associated with clubfoot (Parker et al., 2009).

2. Materials and methods

The skeleton RMPE-75 is a well-preserved adult male (Bruzek, 2002) between approximately 29–46 years old (Scheuer and Black, 2004, old, Brooks and Suchey, 1990) with a stature of approximately 1.65 m (De Mendonça, 2000) from a medieval graveyard (13th–15th century) at Rossio Marquês de Pombal, Estremoz, SE Portugal. From this graveyard, 115 graves were excavated containing a total of 142 individuals (77 adults and 65 non-adults).

The morphology of the foot bones was described and their anomalies were compared to those observed in other studies (e.g. Brothwell 1967; Morse 1978; Roberts et al., 2004; Wright, 2011). Measurements of foot and long bones were taken from the right and left sides, allowing an examination of asymmetry and comparison of bone sizes between this individual and the male adults from the same site. Robusticity indexes (Bass, 1987) were also calculated for the male adults. Entheseal and articular degenerative changes were compared between sides of the skeleton.

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3. Results

3.1. Foot bones morphology

In general, the right tarsals are smaller than the left ones, except for the medial cuneiform length (Table 1). The posterior articulation of the right talus with the calcaneus is the most dimorphic part of the bone in size and is also more concave than on the left bone. Both articular surfaces show lipping and eburnation, on the superior lateral side of the right articulation (Fig. 1). On the right calcaneus, the posterior articulation for the talus is shorter than on the left side and the anterior articulation is absent. At the right sulcus calcanei, there is eburnation and a longitudinal lesion with the lateral side on a lower plane than the medial side, suggesting a pressure fracture (Fig. 1) as a consequence of the tridimensional alteration of the foot. Besides being the only tarsal bone larger on the right side, the right medial cuneiform is flattened in the lateral-medial dimension and the facet that articulates with the 1st metatarsal is absent (Fig. 2). The right 1st metatarsal articulates with the medial surface of the medial cuneiform instead, leading to the metatarsals being medially rotated (Fig. 3). The remaining right tarsals are smaller than the left ones but have normal morphology.

The right metatarsals show the most evident morphological alterations (Fig. 4). The 1st metatarsal is smaller than the left one and shows morphological changes on the proximal articulation, which also shows lipping. The remaining four metatarsals have proximal extremities that are curved laterally and distal extremities curved medially, resulting in a slight “S” shape. The 2nd metatarsal articulates with the medial cuneiform in a more distal part of the metatarsal and where the facet for the articulation with the 1st metatarsal should be. The base of the 3rd metatarsal is narrowed with articular surfaces only on the medial side. The distal articular surface of the 4th metatarsal is located inferiorly instead of dorsally and it articulates with the 3rd and 5th metatarsals through pseudo-facets in a more distal position. The 5th metatarsal is thickened, with irregular morphology, and its articular surface for the 4th metatarsal is curved instead of flat. The 5th metatarsal articulates with the 4th metatarsal at half of its length and has altered morphology with bony growths, which can be related to the insertions of the plantar interossei muscles, responsible for the adduction of the 5th toe. These changes on the metatarsals result in a narrowed foot, curved in both the superior-inferior and lateral-medial planes (Fig. 4). Out of the phalanges of both feet, only the right 1st proximal phalanx was recovered, which

Table 1
Measurements (Wright, 2011) from left and right foot bones and difference between the left and right measurement.

Measurement (mm)	RMPE-75		
	Left	Right	Left - Right
Talus length	55.75	52.85	2.9
Talus width	44.57	41.1	3.47
Medial deviation of the talar neck	16°	25°	-9°
Talus/Calcaneus height	58.4	54.83	3.57
Calcaneus length	75.46	74.54	0.92
Calcaneus width	41.91	38.33	3.58
Navicular length	38.02	36.4	1.62
Navicular width	29.14	27.94	1.2
Navicular height	19.62	19.21	0.41
Cuboid length	37.03	35.15	1.88
Cuboid minimum width	21.34	20.98	0.36
Cuboid posterior height	24.23	22.55	1.68
Cuboid anterior height	13.76	13.71	0.05
Medial cuneiform length	30.23	37.54	-7.31
Medial cuneiform width	22.31	21.32	0.99
Medial cuneiform height	17.17	16.97	0.2
Intermediate cuneiform length	17.66	17.46	0.2
Intermediate cuneiform width	14.67	13.69	0.98
Intermediate cuneiform height	20.86	18.68	2.18
Lateral cuneiform length	22.45		
Lateral cuneiform width	13.89	12.71	1.18
Lateral cuneiform height		23.42	
1st Metatarsal length	60.41	60.83	-0.42
1st Metatarsal head width	24.67	22.09	2.58
1st Metatarsal head height	21.64	19.81	1.83
1st Metatarsal base width	19.71	23.65	-3.94
1st Metatarsal base height	27.49	29.97	-2.48
1st Metatarsal shaft diameter	13.75	13.74	0.01
2nd Metatarsal length	70.81	74.02	-3.21
2nd Metatarsal head width	10.63		
2nd Metatarsal head height	16.79	16.3	0.49
2nd Metatarsal base width	14.04	10.88	3.16
2nd Metatarsal base height	18.08	18.99	-0.91
2nd Metatarsal shaft diameter	8.94	10.79	-1.85
3rd Metatarsal length	65.66	66.15	-0.49
3rd Metatarsal head width			
3rd Metatarsal head height	14.3	13.53	0.77
3rd Metatarsal base width	9.79	8.2	1.59
3rd Metatarsal base height	18.98	19.82	-0.84
3rd Metatarsal shaft diameter	7.79	7.08	0.71
4th Metatarsal length	62.51		
4th Metatarsal head width			
4th Metatarsal head height	15.15	14.83	0.32
4th Metatarsal base width	11.16	10.68	0.48
4th Metatarsal base height	14.84	15.91	-1.07
4th Metatarsal shaft diameter	6.02	5.65	0.37
5th Metatarsal length	67.89		
5th Metatarsal head width	8.69		
5th Metatarsal head height	13.13		
5th Metatarsal base width	19.17		
5th Metatarsal base height	12.34		
5th Metatarsal shaft diameter	9.6		

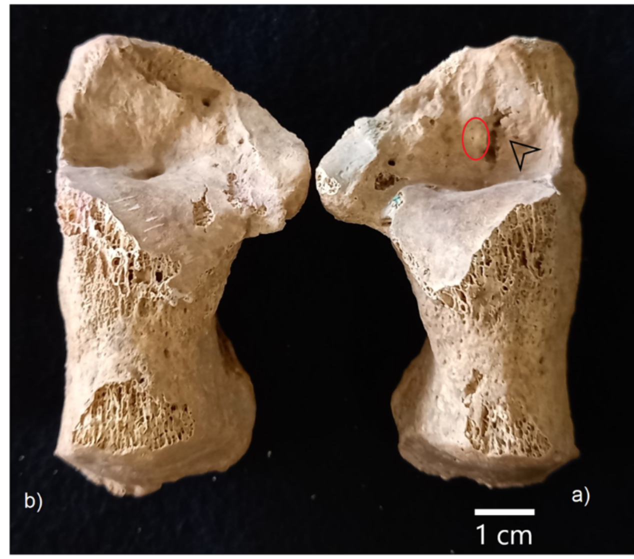

Fig. 1. Right (a) and left (b) calcaneus (superior view). The eburnation is circled in red and the arrow points to the possible pressure fracture on the right calcaneus.

Fig. 2. Right (a) and left (b) medial cuneiforms. It is possible to observe the absence of the facet (area circled in red illustrate where the articular facet should be) that articulates with the right 1st metatarsal. Distal view (view from the 1st metatarsal).

Fig. 3. Articulated right foot bones showing the medial rotation of the metatarsals.

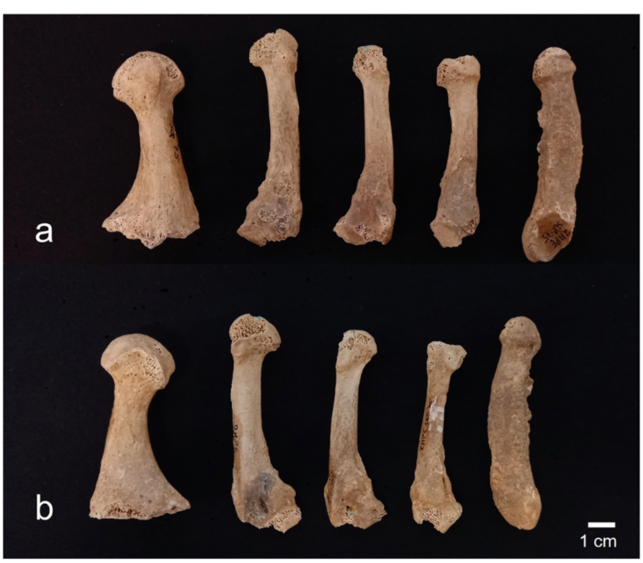

Fig. 4. Morphological alterations on the right metatarsals. a) medial side; b) lateral side.

does not show any morphological changes.

3.2. *Implications for locomotion*

Both the right femur and tibia are medially rotated, and the neck of the right femur forms a larger angle than on the left femur. The articulation of the left knee shows lipping and a large area of eburnation on the medial articulation of both bones (Fig. 5), possibly secondary to a varus of the knee. Most of the entheseal changes on the lower limbs are similar (Supplement). The right forearm is more robust than the left but the left clavicle is more robust than the right (Table 2). The entheseal changes are more marked on the left arm (Supplement). Both wrists show lipping around the articular surface and eburnation, but these are more marked on the right (Fig. 6). There are new bone formations on the lunate bones (Fig. 7d and e), at the articulation to the capitate, and eburnation on the articulation to the ulna (Fig. 7b and c). Both trapezoids and capitates show degenerative changes, as well as the right hamate, the distal articulation of the first right metacarpal and the proximal articulation of the second right metacarpal. All ribs and thoracic vertebrae have degenerative changes on the costovertebral joints, these being more pronounced on the right side, indicating roto-scoliosis.

4. Discussion

The hindfoot (tali, calcanei, cuboids, and naviculars) was the most affected region in the previously published cases (Owsley and Mann 1990, Roberts et al., 2004, Wright, 2011), contrary to the midfoot anomalies (medial cuneiform and metatarsals) observed in RMPE-75.

The foot anomalies observed in RMPE-75 suggest a foot rotation mostly on the lateral-medial plane (talipes varus). This can help explain the lesser degree of bilateral asymmetry in the lower limbs of RMPE-75 than in other cases (e.g. Owsley & Mann 1990; Roberts et al., 2004; Wright, 2011) as the right leg could potentially support more weight and aid in the locomotion more so than in other cases of clubfoot. This study suggests high variability in morphological alterations, which can also help explain the low number of cases from archaeological collections, when the foot bones are not all present, despite clubfoot being one of the most common congenital deformities in the modern era (Ponseti, 1996).

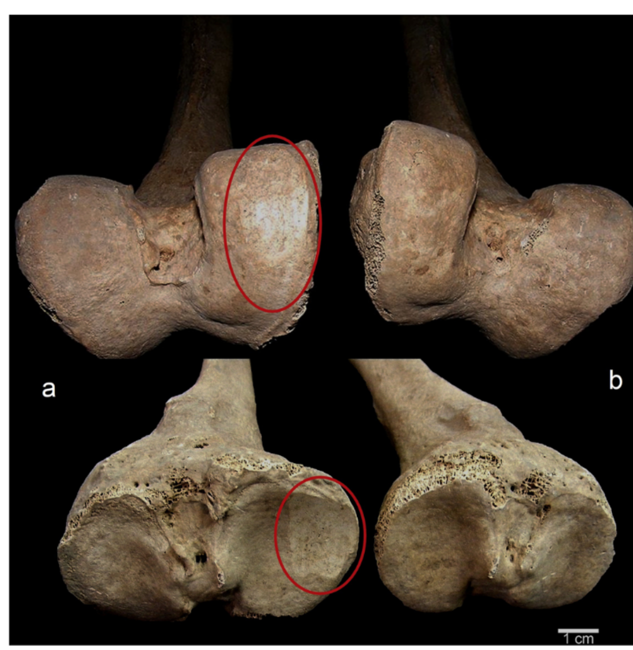

Fig. 5. Eburnation on the medial facet of the left femur and tibia (within the red circles). It is possible to observe the asymmetry between the right (a) and left (b) articulations.

Table 2
Long bone measurements and robusticity index (Bass, 1987) for RMPE-75 and mean calculated for the adult males from the same collection. Measurements from the articular surfaces of the tibia were taken as mentioned in the table.

Measurement (mm)	RMPE-75		Adult male mean			
	Right	Left	Right	N	Left	N
Clavicle maximum length	144.00	140.97	142.94 ± 9.20	18	145.72 ± 8.34	20
Clavicle robusticity index	2.22	2.48	2.71 ± 0.28	18	2.66 ± 0.19	20
Humerus maximum length	312.00	310.00	322.43 ± 22.26	23	313.6 ± 14.74	15
Humerus robusticity index	2.08	2.03	2.01 ± 0.13	23	2.02 ± 0.11	15
Radius maximum length	235.00	235.00	242.43 ± 10.10	23	236.9 ± 9.07	20
Radius robusticity index	1.79	1.66	1.77 ± 0.09	23	1.77 ± 0.13	20
Ulna maximum length	251.00	256.00	260.10 ± 10.14	21	262.8 ± 13.35	15
Ulna robusticity index	1.51	1.37	1.46 ± 0.10	21	1.40 ± 0.07	15
Femur maximum length	438.00	439.00	437.38 ± 22.83	22	440.85 ± 24.97	20
Femur physiological length	432.00	438.00	435.00 ± 23.63	22	436.5 ± 24.73	20
Vertical diameter of the femoral head	44.95	44.31	46.74 ± 2.77	26	46.39 ± 2.99	22
Femur bicondylar width	74.95	77.20	75.36 ± 4.12	21	75.06 ± 4.35	18
Femur robusticity index	2.01	2.05	2.04 ± 0.10	22	2.02 ± 0.09	20
Femoral neck angle	140°	125°				
Tibia maximum length	344.00	353.00	354.32 ± 18.7	22	359.68 ± 22.34	19
Tibia robusticity index	2.03	1.98	2.09 ± 0.12	22	2.05 ± 0.11	19
Tibia proximal articulation (antero-posterior)	44.76	48.60				
Tibia proximal articulation (medio-mesial)	70.00	77.82				
Tibia distal articulation (antero-posterior)	37.48	38.26				
Tibia distal articulation (medio-mesial)	45.25	46.60				

Fig. 6. Distal articular surface of the ulnae. The left (b) articular surface is enlarged and with a larger eburnation than on the right (a) ulna.

The few cases of clubfoot can also be related to the difficulty of finding reference to them in the "grey literature", osteological reports, or theses (e.g. Connell et al., 2012). Since there are no signs of trauma or infection in the lower limb (or any other bone except for the trauma on the 7th right rib), this case does not seem to correspond to an acquired foot deformity but to a congenital foot deformity, probably clubfoot.

Additional to the anomalies on the right foot bones, this individual also has other congenital anomalies: an asymmetric cranium and a palatal inclusion cyst in a median anterior position within the incisive canal. About 80 % of clubfoot cases are isolated and have an idiopathic aetiology (Wynne-Davies, 1972), while the remaining are associated with other malformations and genetic syndromes (a list of these syndromes can be found in Sadler et al., 2019). An example of this is the case of two Portuguese sisters, with consanguineous parents, having several malformations including clubfoot (Sousa et al., 2014).

Fig. 7. Hand bones of RMPE-75. a) first right metacarpal (medial view); b) and d) right lunate; c) and e) left lunate. b) and c) are in superolateral view (view from the radius); d) and e) are in an inferomedial view (view from the triquetrum).

The coxa valga observed on the right femur suggests reduced locomotor stress of the right lower limb (Trinkaus, 1993) and was also observed in other cases (Roberts et al., 2004). The entheseal changes observed on the lower limbs suggest that the left leg would have been more frequently flexed (knee and ankle joints), as occurs during walking, than the right leg. The possible compression trauma observed on the right calcaneus (Fig. 1) can be related to the distribution of weight towards the lateral side of the foot while using the right leg. The degenerative alterations on the left upper limb suggest more intense or frequent movement rising the clavicle, flexing the elbow, the wrist, and hand on this side. The alterations on the right forearm, suggest that more weight (or longer support) was applied to the right wrist, maybe in a static position.

5. Conclusion

The diagnosis for the anomalies observed on the foot bones of this individual is clubfoot, the talipes varus variation. This anomaly on the right foot led to changes in locomotion, possibly aided by two crutches. The limbs that would support most of the weight would be the left leg and the right arm, particularly in a static standing position. The alterations observed on the ribs and vertebrae suggest a slight slant to the right side, possibly associated with directing most of the weight of the upper body to that side.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ijpp.2022.05.004.

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