
The limb bones of *Myotragus balearicus* Bate, 1909

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ABSTRACT

The limb bones in *Myotragus balearicus* are described and their functional morphology is discussed. The morphological characters of the short and robust limb bones are related to an increase in stability and in the moment arm of muscles. Some of these characters do not occur in recent species of Bovidae. *M. balearicus* can be described as a small, short-limbed and robust bovid. Its fore quarters are relatively longer and more heavily built than the hind ones, and the fore feet are relatively wide apart. The hypothesis that *M. balearicus* was adapted to a mountainous environment is rejected on morphological grounds.

INTRODUCTION

The Pleistocene endemic mammal faunas of the Mediterranean islands are characterized by the small number of species. The large species are represented by dwarf elephants, dwarf hippos and various ruminants, and the carnivores are completely absent (Sondaar, 1977). Studies of the postcranial skeleton of the dwarf hippopotamus *Phanourios minor* from Cyprus (Houtekamer and Sondaar, 1979) and the Pleistocene deer from Crete (De Vos, 1979) indicate that the limb bones in these species show various adaptations which are believed to result from the island environment.

The bovid *Myotragus balearicus* Bate, 1909 is the only large mammal in the Pleistocene fauna of Mallorca and Menorca. The skull of this species is characterized by the robust masticatory apparatus (including two continuously growing lower incisors), and the rostrally facing orbita. The postcranial skeleton is characterized by the relatively short and robust limbs. Andrews

(1914) described the postcranial bones, and Leinders and Sondaar (1974), Moya-Sola (1978) and Leinders (1979) discussed some functional aspects of the bones of the hind and fore foot. In addition to a previous study on the body proportions in *M. balearicus* (Spoor, 1988), this paper describes the morphological characters of its limb bones, and discusses some of their functional aspects.

MATERIAL AND METHODS

The material of *M. balearicus* which is studied in this paper was excavated in the caves Son Muleta (in the collection of the Deia Archaeological Museum, Mallorca), Son Maiol, Cova des Moro (stored in the Institute of Earth Sciences, Utrecht) and Cova de la Barxa (type locality, in the collection of the British Museum of Natural History, London). The description and bibliography of these sites are given by Moya-Sola and Pons-Moya (1979). The recent artiodactyl species to which *M. balearicus* is compared, are in the collections of the Rijksmuseum van Natuurlijke Historie, Leiden, the British Museum of Natural History, London and the Institute of Earth Sciences, Utrecht. Comparative measurements from limb bones with fused epiphyses were taken with Vernier callipers to the nearest millimetre. The method of measuring is shown in figure 1. The skeletal material of the recent Caprinae that was measured is listed in table 1.

DESCRIPTION, COMPARISON AND FUNCTIONAL ASPECTS

All indices given for *M. balearicus* (table 2) were calculated for the material from Son Muleta. The indices of robustness (sagittal diameter as a percentage of the length; fig. 1: $D/L \times 100$) of the limb bones in *M. balearicus* are after Spoor (1988), and those in recent species of Bovidae are after McMahon (1974)

Table 1. The measured skeletal material of the recent Caprinae. BM: British Museum of Natural History, London, RMNH: Rijksmuseum van Natuurlijke Historie, Leiden, REC: Institute of Earth Sciences, Utrecht.

<i>Ammotragus lervia</i> , REC 409, 410
<i>Budorcas taxicolor</i> , BM 1935.10.4.1, 1885.8.1.367
<i>Capra caucasica</i> , RMNH 4357
<i>Capra ibex</i> , RMNH 1893; REC 403
<i>Capricornis crispus</i> , RMNH –
<i>Capricornis sumatraensis</i> , RMNH 991, cat.h; REC 402, 403
<i>Hemitragus jemlahicus</i> , RMNH 2306
<i>Oreamnos americanus</i> , BM 1889.3.10.1, 1889.11.7.1
<i>Ovibos moschatus</i> , RMNH cat. a, cat. b
<i>Ovis ammon musimon</i> , RMNH 26106
<i>Ovis vignei</i> , RMNH 12826
<i>Rupicapra rupicapra</i> , RMNH 1376
<i>Saiga tatarica</i> , RMNH 10948
<i>Capra hircus</i> and <i>Ovis aries</i> , several, often uncatalogued specimens

and Spoor (1988). Unless otherwise specified, the comparison is made with the morphology of the limb bones in the recent Caprinae, excluding the considerably larger takin, *Budorcas taxicolor*, and musk-ox, *Ovibos moschatus*.

Humerus (plate 1.1)

The humerus is short and stout. Its index of robustness (17) is larger than that of the Caprinae (11–14).

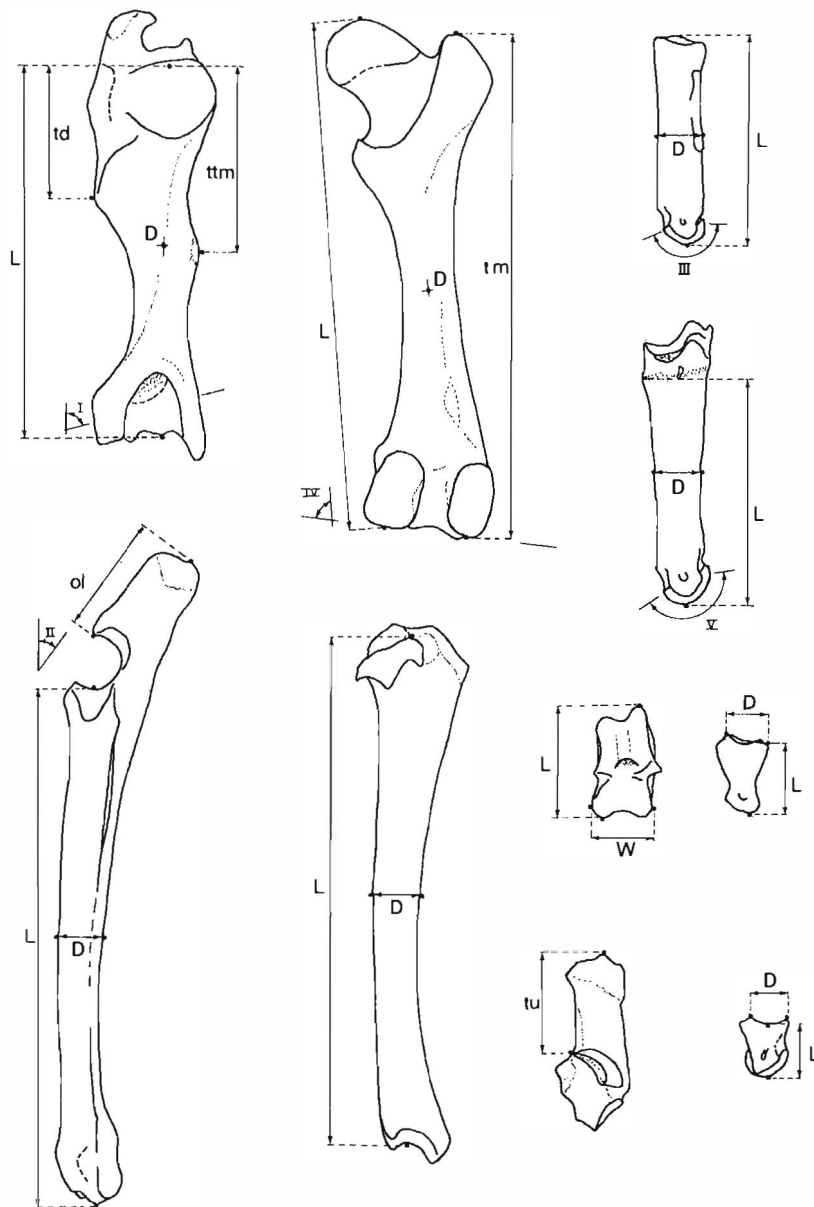


Figure 1. Method of measuring the limb bones of *Myotragus balearicus*.



Plate 1. *Myotragus balearicus* (Son Maiol). 65% of natural size. 1. left humerus; a. medial, b. cranial, c. lateral and d. proximal aspect. 2. right ulna/radius; lateral aspect. 3. left os femoris; a. cranial and b. medial aspect. 4. left tibia; cranial aspect.

Table 2. Indices of the limb bones of *Myotragus balearicus* from Son Muleta, Mallorca. Abbreviations refer to figure 1. All indices $\times 100$. *: calculated using mean lengths, see Spoor (1988). **: calculated by E. Sanders (Deya Archaeological Museum, Mallorca).

	n	\bar{x}	SD	range
td/L hum.	114	46	2.3	40-52
ttm/L hum.	114	48	2.0	43-53
ol/L rad.+ l. mc.	40/70+210	18*	-	-
tm/L o.fe.	111	99	1.6	93-102
W/L talus (**)	360	61	-	59-66
tu/L mt.	106/117	37*	-	-

Both articulation surfaces are obliquely positioned to the diaphysis (plate 1.1b). The angle between the distal trochlea and the diaphysis (fig. 1:1) is between 62 and 77 degrees. Among the recent artiodactyls the same angle was observed in species of Suina like the peccary, *Tayassu albirostris*, and the recent pygmy hippopotamus, *Choeropsis liberiensis*, but the angle is larger in the Caprinae (82-88 degrees). Due to the oblique position of the humeral articulation surfaces the fore limbs of *M. balearicus* must have stood relatively wide apart.

The caudal part of the tuberculum majus is small, and the place of insertion of the m. infraspinatus, which is large and round in recent Bovidae is cranio-caudally constricted (plate 1.1c). The proximal end of the sulcus intertubercularis is abrupt and situated about 5 mm above the surface of the caput (plate 1.1d). In recent species of Bovidae (and most other Artiodactyla) the proximal end of the sulcus and the caput are at the same level. Only in *Anoa depressicornis*, considered by Thenius (1969) as the most primitive recent bovid, is the morphology of the sulcus intermediate between *M. balearicus* and the other Bovidae. In *Choeropsis liberiensis* the raised proximal end of the sulcus resembles that in *M. balearicus*.

The tuberositas deltoideus and tuberositas teres major are very well developed, and situated relatively distad. Their relative position indices (fig. 1: td/1 $\times 100$ and ttm/1 $\times 100$) are 46 and 48 respectively. In the Caprinae the index of the tuberositas deltoideus is between 29 and 42, and that of the tuberositas teres major between 34 and 45. The origin of the M. deltoideus on the spina scapulae is also well marked.

The epicondylus medialis has a distal projection on which the Mm flexor digit. superficialis and profundus probably had their origin (plate 1.1a).

If compared to the recent Caprinae the dimensions of the humerus increase the moment arm of the M. biceps brachii, M. deltoideus and M. teres major about the shoulder joint and that of the digital flexors (as extensors) about the elbow joint.

Ulna/radius (plate 1.2)

The diaphysis of the radius is only slightly bent, and that of the ulna is less reduced and less flattened than in recent species of Caprinae. The index of robustness (11) is within the range of the recent Caprinae (7-12).

The olecranon is relatively short if compared to the length of the radius. However, the length of the olecranon as a percentage of the length of the radius plus the metacarpal bone (fig. 1: ol/L radius + L os metacarpale) gives a better impression of the relative moment arm of the *M. triceps brachii* about the elbow joint. This index in *M. balearicus* (18) is large but within the range of the recent Caprinae (10–18). The long axis of the olecranon makes an angle of about 32 degrees with the radius (fig. 1: II), which is somewhat larger than in most species of Caprinae. This angle in *M. balearicus* is comparable to that in other relatively short-limbed artiodactyls (e.g. various races of *Ovis aries*, Suina and large Bovidae), and might be related to the limb length.

Ossa carpi

In general the ossa carpi have normal caprine proportions. The stop facets on the extensor (distal) side are well developed, which might favour stability and the transmission of forces along the axis of the fore limb. Manipulation of the ossa carpi of a single complete individual of *M. balearicus* from Cova des Corral des Porcs indicates that the flexion in the proximal and mid carpal joint is less than the 90 and 75 degrees respectively observed by Yalden (1971) in various ruminants.

Os metacarpale (plate 2.5)

The diaphysis of the os metacarpale (III + IV) is hardly constricted either lateromedially or dorsopalmarly, which gives this bone its specific rectangular shape. The index of robustness of the os metacarpale in *M. balearicus* (22) is considerably larger than in any of the living ruminants (Bovidae: 7–16). Even the os metacarpale in *Budorcas taxicolor*, which largely resembles that in *M. balearicus*, is more slender. Sometimes rudiments of ossa metacarpalia II and V are present, situated at the level of the middle of the diaphysis of III + IV.

The capita are wide and the articulation surfaces extend over about 180 degrees (fig. 1: III), which is considerably less than in the recent Bovidae (220–260 degrees). The difference is due completely to the reduced surface on the dorsal side in *M. balearicus*, which points to a limited range of extension in the metacarpophalangeal joints (Leinders, 1979).

Os femoris (plate 1.3)

The os femoris is short and stout and has an almost straight diaphysis. Its index of robustness (13) is larger than that of the Caprinae (8–10).

The proximal part (including the caput and the trochanter major and minor) and the distal condyles are positioned obliquely to the diaphysis. The angle between the tangent to the condyles and the diaphysis (fig. 1: IV) is 80 to 85 degrees, which is somewhat smaller than in recent species of Caprinae. Due to this obliquity the hind limbs of *M. balearicus* must have been relatively wide apart, though less than the forelimbs.

The caput is large and round. The fossa trochanterica is narrow and the robust and round trochanter major does not project above the caput. The

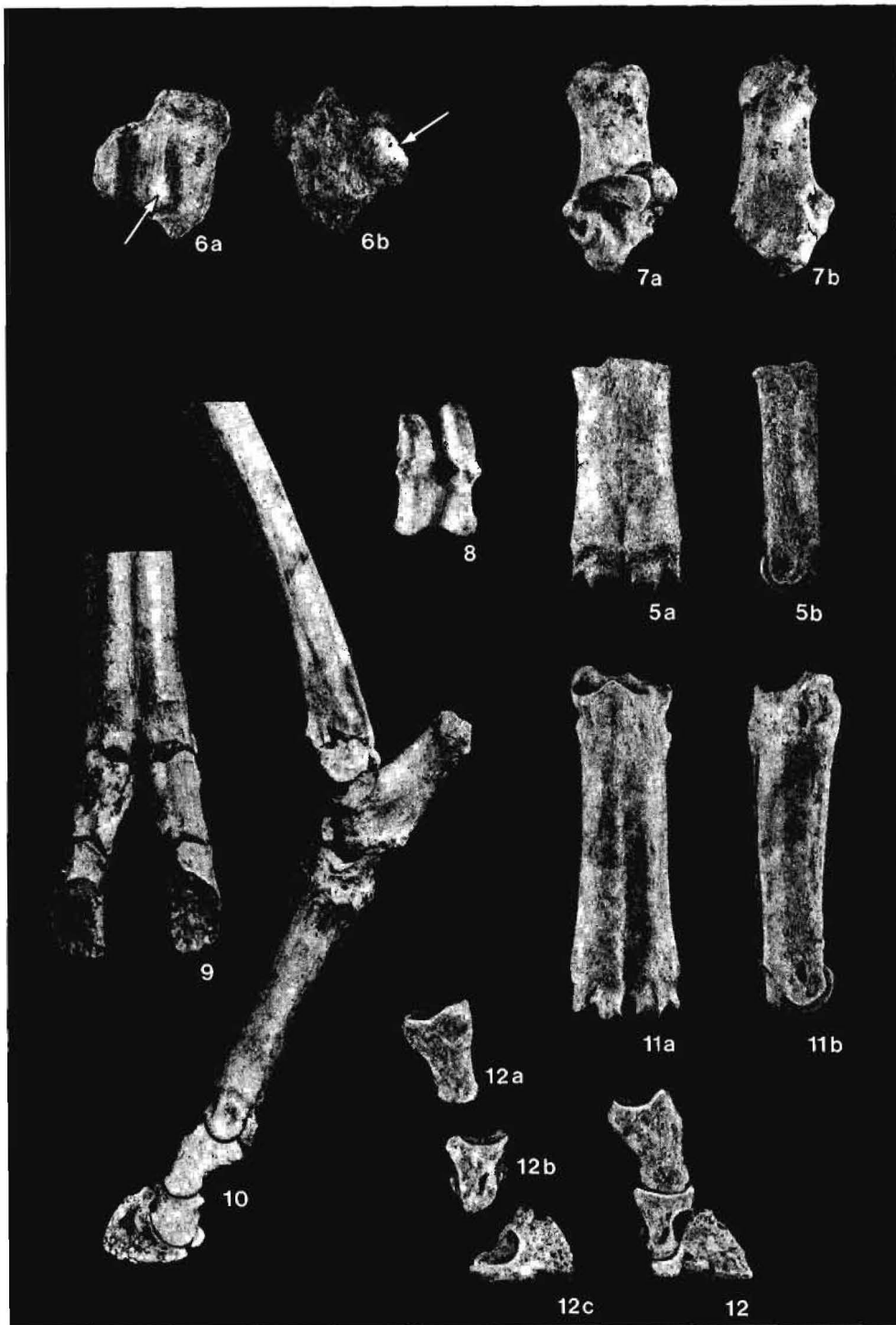


Plate 2. *Myotragus balearicus* (Son Maiol, except 9 and 10 Son Muleta). 65% of natural size. 5. right metacarpal bone; a. dorsal and b. lateral aspect. 6. right patella; a. caudal and b. cranial aspect. 7. right calcaneus; a. medial and b. lateral aspect. 8. left talus; dorsal aspect. 9. left hind-foot; dorsal aspect. 10. left hind-foot; lateral aspect. 11. left metatarsal bone; a. dorsal and b. lateral aspect. 12 phalanges; axial aspect.

relative position index of the trochanter major (fig. 2: $tm/L \times 100$) is 99 in *M. balearicus*. Its range (93–102) overlaps with that in the recent Caprinae (101–104). The area for the insertion of the gluteal muscles on the trochanter major is large and well-marked, which correlates with the large origin of these muscles on the remarkably wide iliac wings of the os coxae. This bone is further characterized by a short and high os ischii, a tuber ischiadicus which consists of only a single projection (probably the processus cranialis), and the relatively vertical position of the os ilium. This morphology of the os coxae, and the low and robust trochanter major are more typical for heavy-built mammalian species than for speedy ruminants. Hence, the os coxae in *M. balearicus* resembles that in *Choeropsis liberiensis* more than that in bovids.

The condyles are wide and flat and the fossa intercondylica is narrow. The trochlea is wide and very short since the proximal part is absent; instead the trochlea is proximally bordered by a shallow depression (plate 1.3a). The medial ridge of the trochlea has a round edge and is slightly longer than the lateral one, which has a sharp edge.

Patella (plate 2.6)

The patella is characterized by a large process on the medial side, on which the place of insertion of the *M. vastus medialis* is strongly marked (plate 2.6b). When articulated the medial process curves over the round medial edge of the trochlea of the os femoris. Among the ungulates, especially the patella in *Choeropsis liberiensis* resembles that in *M. balearicus*.

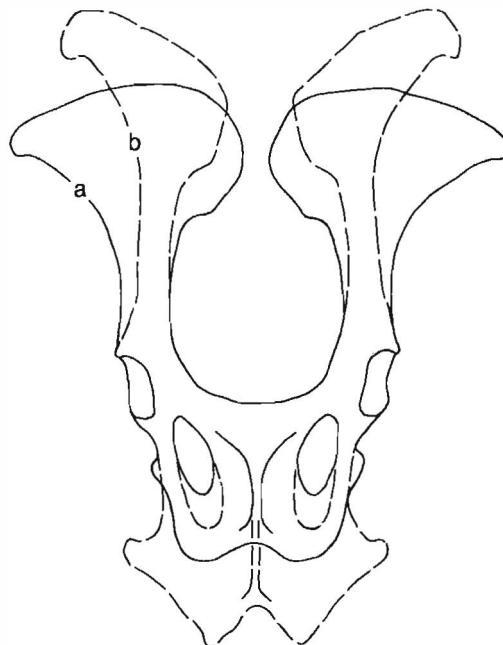


Figure 2. The silhouette of the os coxae (male) in *Myotragus balearicus* (a) and *Capra hircus* (b).

The distal end of the articulation surface of the patella bears a slight eminence (plate 2.6a), which fits into the depression proximal of the femoral trochlea when the patella is drawn upward to its maximum extent. In this position the medial process of the patella hooks behind the proximal end of the medial trochlear ridge.

The type of articulation between the patella and the os femoris points to some kind of patellar locking mechanism. However, aspects like the increase of insertion surface for the *M. quadriceps femoris*, and stabilization of the femoropatellar joint are related to the size of the medial process as well.

Tibia (plate 1.4)

The tibia is relatively short but its morphology resembles that in the recent Bovidae. Its index of robustness (10) is larger than that in the Caprinae (6–8).

Ossa tarsi (plate 2.7,8,10)

The relative width of the talus (fig. 1: $W/L \times 100$) is 61, i.e. it is relatively high. However, the range of this index in *M. balearicus* overlaps with that of the Caprinae (64–71).

The talus is characterized by the oblique orientation of the proximal trochlea to its distal fellow, while both are in line in recent Pecora. Generally speaking, an oblique talus is interpreted as a primitive artiodactyl character (Schaeffer, 1947; Webb and Taylor, 1980), such as in the Suina and Tragulidae. Only the talus in *Anoa depressicornis* shows a slight and variable degree of obliquity. In the articulated tarsus the proximal trochlea is in line with the axis of the foot, since the articulation of the talus with the os centroquartale compensates for the effect of the obliquity. Simulated flexion of the ankle joint in *M. balearicus* hardly indicates any deviation from the movements possible in this joint in recent Caprinae.

The calcaneus has a short and robust tuber. However, the tuber length relative to the length of the metatarsal bone (fig. 2: $tu/L \text{ os metatarsale} \times 100$) is 37 in *M. balearicus*, and within the observed range of the Caprinae (25–37). Therefore the relative moment arm of the *M. gastrocnemius* and the *M. flexor digit. superficialis* about the ankle joint in *M. balearicus* is large, though not in an unusual way.

The os centroquartale and os tarsale 1–3 are always fused. About 60% (Son Mayol) and 75% (Son Muleta and Cova des Moro) of the metatarsal bones are fused with these tarsal bones. This fusion can be found in metatarsal bones with fused as well in those with unfused distal epiphyses, and is therefore independent of the age of the animal. Fusion of the centroquartal, first, second and third tarsal bones also occurs in *Okapia johnstoni* (Grassé, 1955), *Budorcas taxicolor* and *Pudu pudu*. Fusion with the metatarsal bone is only known from other fossil island ruminants like *Cervus cretensis* and *Hoplitomeryx matthei* (Leinders and Sondaar, 1974) and occasionally in domestic ruminants.

Since, the non-fused situation is maintained in almost all Pecora, the intertarsal and tarsometatarsal joints are expected to have had a distinct function which

became lost in species with fused ossa tarsi and metatarsale. According to Leinders and Sondaar (1974) contraction of the *M. peroneus longus* moves the os tarsale 1, which results in a slight rotation of the os metatarsale. These authors relate this rotation to “the ability of ruminants to zigzag at full speed in order to escape predators”. Experimental research (electromyography of the involved muscles and cinephotographical analysis of ruminant locomotion) is necessary to test this hypothesis. The tarsometatarsal joint might have a function in the absorption of impact stress which occurs in the hind limb during fast locomotion. Whatever the function of the intertarsal and tarsometatarsal joints may be in ruminants, the observed fusion in *M. balearicus* increases the stability of the tarsal region.

Os metatarsale (plate 2.11)

The index of robustness of the short os metatarsale III + IV (21) is larger than that of any of the recent ruminants (Bovidae: 6–16). The distal end of the sulcus dorsalis is open, which is a diagnostic character of the Bovidae (Heintz, 1970). The articulation surface of the distal capita (fig. 2: V) extends over about 160 degrees, which is far less than in the recent species of Bovidae (210–250 degrees).

Phalanges (plate 2.12)

The phalanges of the fore limb are generally stouter than those of the hind limb. However, since it is not possible to identify isolated specimens they are discussed in general.

The indices of robustness of both phalanx I and II (56 and 73) are larger than those in the Caprinae (31–43 and 42–63). The distal caput of phalanx I, especially the axial (inner) part, is flat (plate 2.12a), as is the corresponding proximal base of phalanx II (Leinders, 1979). The axial part of the distal head of phalanx II is small. It is divided into a dorsal part that articulates with phalanx III, and a palmar/plantar part that articulates with the distal sesamoid. Both surfaces are at an angle of less than 90 degrees to each other (plate 2.12b). Phalanx III is very short (plate 2.12c). The axial articulation facet is small, and the tip is axially directed.

The shape of the proximal interphalangeal joints suggests a relatively limited range of flexion, and the articulation of the distal sesamoid and the phalanges II and III points to even fewer movements in the distal interphalangeal joint. Probably the phalanges had a relatively upright position, radiating from the axis of the foot (plate 2.9, 10).

PREDICTION OF THE BODY WEIGHT

Scott (1983) used 45 dimensions of the postcranial skeleton of 108 species of recent Bovidae (580 individuals) to calculate the variables in the allometric equation which relates these dimensions to body weight. The body weight of *M. balearicus* from Som Maiol and Cova des Moro has been calculated using 10 of the best correlated dimensions (table 3). These dimensions are the

Table 3. Estimated body weights (W) of *Myotragus balearicus* in kilograms, after the method of Scott (1983). The codes of the measurements are explained in the text.

measurement	Son Maiol		Cova des Moro	
	n	W	n	W
H3	17	41	35	27
H4	16	45	53	33
R2	15	46	51	33
R5	12	42	42	32
Mc2	27	41	46	31
F2	22	32	12	21
F5	16	28	21	20
T2	17	23	38	17
T4	17	28	49	20
Mt2	20	42	58	26

lateromedial diameter of the proximal articulation surface of the humerus (H3), the radius (R2), the os metacarpale (MC2), the tibia (T2) and os metatarsale (MT2), that of the distal articulation surface of the humerus (H4), the radius (R5), the os femoris (F5) and the tibia (T4), and the distance between the trochanter major and minor of the os femoris (F2). The exact method of measuring and the variables of the allometric equations are given by Scott (1983).

Since the bones from Son Maiol are generally larger than those from Cova des Moro, the deduced body weight for the former site is also larger than that for the latter. The five body weights derived from the dimensions of the fore limb correspond quite well. The four deduced from the os femoris and the tibia also give a corresponding result, whereas that from the metatarsal bone is considerably higher. The correct measurement of the proximal articulation surface of the latter may have been hampered by the fusion with the ossa tarsi. In both sites the estimated body weights are remarkably higher for the fore limb than for the hind limb. From this it can be concluded that in *M. balearicus* the fore limbs carried a larger percentage of the body weight than in the recent Bovidae. Consequently the centre of gravity must have been more cranially located in *M. balearicus* than in the recent Bovidae.

DISCUSSION

The postcranial skeleton of the small *M. balearicus* resembles that of the large Bovidae (e.g. *Bos*, *Bison*, *Bibos* and *Bubalus*) in many aspects (e.g. the short limbs and the robustness of the limb bones). However, these proportions can largely be explained by a simple process of shortening from generalized caprine proportions to those found in *M. balearicus* (Spoor, manuscript). Shortening of the limb bones, especially the distal ones, occurred in various other island mammals (Sondaar, 1977; de Vos, 1979), although it was never as pronounced as in *M. balearicus*. Some of the morphological characters in *M. balearicus* seem to be largely related to the process of shortening.

In the humerus the overall proportions of the proximal structures (as far distad as the deltoid and teres major tuberosities) and the distal condyle are comparable to those in caprine humeri. The shortening of the humerus apparently occurred only in the distal half of the diaphysis, and therefore the deltoid and teres major tuberosities have a relatively distal position. Comparably the shortening of the os femoris took place exclusively in the diaphysis distad of the trochanter minor. While the relative moment arms of the *M. deltoideus* and *M. teres major* are increased by the shortening, those of the *M. triceps brachii*, *M. gastrocnemius* and *M. flexor digit. superficialis* are hardly increased at all, because of the proportional shortening of the olecranon and the tuber calcanei.

Since the ulna/radius in *M. balearicus* are not shortened, whereas all other limb bones are, its forelimb is relatively long compared to the hind limb. Consequently the intermembral index (fore limb length as a percentage of the hind limb length) is higher in *M. balearicus* than in recent bovids (Spoor, 1988). According to Kummer (1959) there is no biomechanical relation between the intermembral index and the distribution of the body weight over the limbs. However, in this aspect *M. balearicus* shows a remarkable analogy with the recent species of Hyaenidae. Both in *M. balearicus* and the recent hyenas (Spoor, 1985; Spoor and Badoux, 1986) the intermembral index is notably higher than in related species (Caprinae and Canidae/Felidae respectively), and in both the centre of gravity is situated relatively cranial. As mentioned above the os coxae in *M. balearicus* has a wide os ilium and a short and high os ischii in comparison with recent Caprinae. The same pattern was observed for the os coxae in the Hyaenidae, compared to that in the Canidae and Felidae (Spoor and Badoux, in press).

The relation between the intermembral index, the position of the centre of gravity and the morphology of the os coxae suggested by these analogies is not yet understood. Since both the hyenas and *M. balearicus* are robustly built animals, the morphology of the os coxae might be related to this robustness, independent of the other two aspects. In the Hyaenidae the cranially positioned centre of gravity is largely the consequence of the relatively long neck and its heavy musculature. Since the neck in *M. balearicus* is not longer than in recent caprinae (Spoor, 1988), the relative cranial position of its centre of gravity is probably due to the well-developed musculature of the fore limbs and the masticatory apparatus. Both the strongly marked places of muscular insertion on the fore limb bones and the relatively robust mandibula with a very hypsodont dentition may justify this conclusion.

The caudally reduced tuberculum majus, the raised end of the sulcus intertubularis and the projection on the medial epicondyle of the humerus, the medial process of the patella and the oblique talus are characters in *M. balearicus* that do not occur in recent species of Bovidae. These characters (except the shape of the talus and the tuberculum majus) as well as the relatively wide positioned fore and hind limbs, the fusions in the tarsal bones, and the short and robust limb bones are related to a gain in stability and an increase

of the moment arms of various muscles. Together with the pelvic proportions, these features indicate that *M. balearicus* had a strong and robust body. The remarkable similarities between some morphological structures in *M. balearicus* and *Choeropsis liberiensis* must be looked upon as analogous adaptations. For the moment it is very difficult to decide whether *M. balearicus* was a relatively heavy animal, since it is impossible to estimate an accurate body weight. Caprines with an equal thoracolumbar spine length as *M. balearicus* (Spoor, 1988), have completely different body weights (Scott, 1983), from those calculated for the latter (table 3).

On the basis of the analysis of the body proportions (Spoor, 1988) and the morphology of the limb bones, *M. balearicus* can be described as a small, short-limbed and robust caprine. Its fore quarters are relatively longer and more heavily built than the hind ones, and especially the fore feet are relatively wide apart.

The scarce postcranial bones of the older species of *Myotragus*, *M. peponellae*, *M. antiquus*, *M. kopperi* and *M. batei* (Alcover, Moya-Sola and Pons-Moya, 1981), indicate that the morphological characters of *M. balearicus* were already present in its ancestors. Only the degree of fusion in the tarsal bones shows a progression from *M. peponellae* to *M. balearicus*. Apparently, the evolution of the postcranial skeleton followed the "quantum-evolution" pattern (a relatively rapid shift to a new adaptive morphology), while the dentition evolved following a phyletic evolution pattern (gradual reduction of the premolars and incisors and an increased hypsodonty). This combination of evolution patterns was observed by Simpson (1951) for the evolution of horses, and by Sondaar (1986) for that of island mammals in general.

Andrews (1914) and Leinders (1979) suggested that *M. balearicus* was adapted to life in a mountainous environment. This conclusion was reached largely on the basis of the occurrence of short metapodial bones in *Budorcas taxicolor* and *Oreamnos americanus*. These species live in the Chinese mountains and the Rocky Mountains, respectively, and have a slow clambering, non-jumping locomotion. However, in aspects other than the metapodial size, the morphology of these species differs profoundly from that of *M. balearicus*. Moreover, the comparison of *B. taxicolor* and *M. balearicus* is obscured by the large difference in body size (Spoor, 1988). The relatively upright position of the short phalanges, and the limited movement in the metacarpo/tarso-phalangeal and interphalangeal joints indicate the absence of an effective shock absorbing mechanism in the feet of *M. balearicus*. This feature and the wide position of the fore and hind limbs does not fit in with an adaptation to a mountainous environment, either with respect to saltatorial locomotion, or to "slow clambering" gaits.

The morphology of the locomotory apparatus in *M. balearicus* seems to be primarily related to a maximum gain in stability in combination with a basically cursorial propulsion pattern (Spoor, 1988). The loss of speed and gracility, which is the consequence of this morphology, is not a discriminating factor since no carnivores were present on Mallorca and Menorca. Although the mor-

phology in *M. balearicus* can be seen as a general adaptation to life on predator-free island, its unusual aberrance points to more specialized adaptations. However, in this respect no well-founded hypothesis can be deduced from the present study. The unknown function of the specialized masticatory apparatus (e.g. the two large permanently growing incisors) might be the key to a more detailed functional interpretation of the morphology of the postcranial skeleton of *M. balearicus*.

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