3 MATERIALS AND METHODS

The analysis of the faunal remains of Kemp's Caves, as well as the development and testing of the program, is a descriptive cross sectional study. The study comprised of three stages, and will be described in this way.

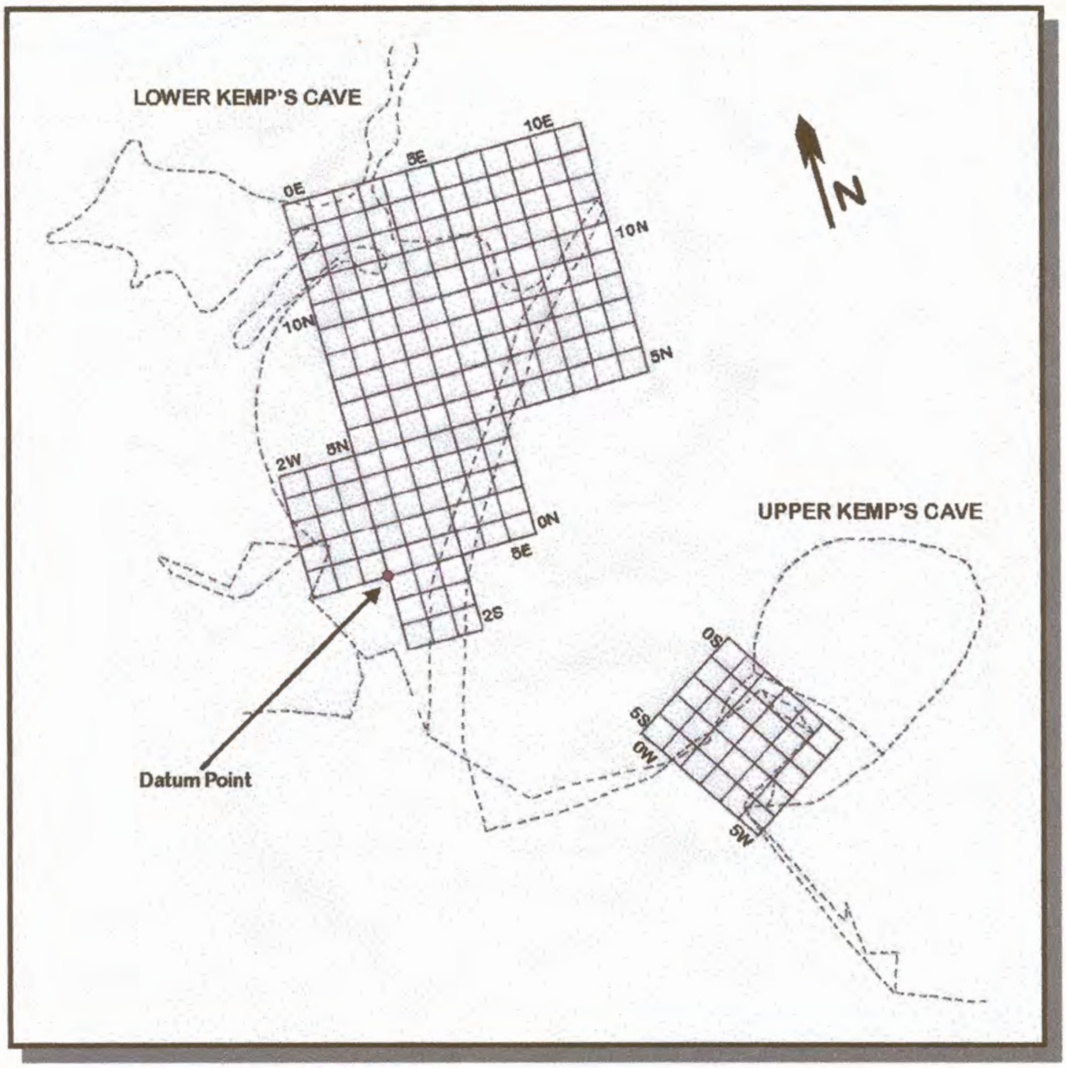
I. STAGE I - FAUNAL ANALYSIS

The purpose of stage 1 was to compose a species list indicating the species (modern or extinct) which occupied Kemp's Caves and its surrounding areas. This was done by classifying and identifying all faunal material of LKC, excavated up to date, using conventional methods. Faunal elements provide a variety of information about the history of a site. If an extinct species is identified among the remains, it is of particular value. The era in which this animal existed may give insight into the date estimates of the rock matrix that the skeletal part was recovered from. This might serve as confirmation of the dating of the entire, or part of, the excavation site.

All microfauna and archaeological artifacts were removed prior to analysis. The bones were obtained from the Department of Anatomy, University of Pretoria. Analysis took place at the Northern Flagship Institution (NFI), the former Transvaal Museum, under guidance of the staff of the Archaeozoology Department. Bones excavated in 1993, 1994, 1997, 1998 and 1999 were utilized for this study. Although the author did excavate for short periods of time at the site, staff and students of the Universities of the Witwatersrand and Pretoria removed most of the bones.

Skeletal parts lodged within decalcified breccia were prepared and both cranial and post-cranial elements were extracted. The sample included modern and fossilized material. Figure 3.1 shows the grid system in LKC.

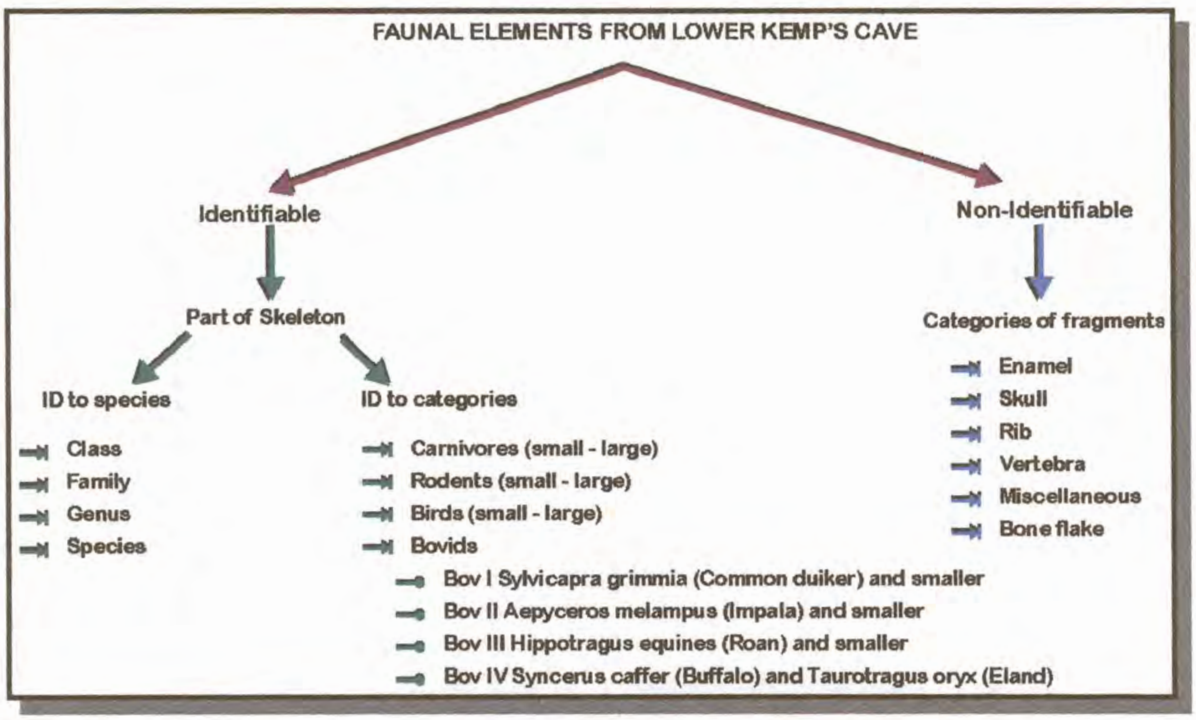
FIGURE 3.1: Site map of Kemp's Caves



Due to the difficulty of acquiring a successful grid system, the transfer of bones from Wits to UP, as well as the fact that the steel wire borders of the grids were stolen, several bones have no grid assigned to them. Although it was attempted to place specimens within a certain area in the cave where possible, attempts were not always successful.

More than eight thousand faunal elements were analyzed and compared with modern skeletal material from the Transvaal Museum. Approximately 900 pieces were identifiable while the rest were unidentifiable. These two groups were dealt with separately. Figure 3.2 is a basic scheme providing the method used to analyze the faunal material of Lower Kemp's Cave.

FIGURE 3.2: Flow diagram of faunal analysis



1.1 Identifiable bones

Identifiable bones were analyzed according to specific criteria. To identify a specific skeletal fragment, the type of bone, that is whether it is a long, short, sesamoid, accessory or irregular bone is the first step to identification. With this information the part of the skeleton from which this bone originated is then established. Next the class, family and genus are ascertained by comparing the fragment with modern skeletal material. If possible, the species is stipulated as well. Fragments not identifiable to species level were put in groups. These groups included carnivores, rodents and birds. Size indications within the classes ranged from small to large. Bovidae size were based on the classification by Brain [87]: Bov I includes the Common Duiker *(Sylvicapra grimmia)* and species smaller than that. Bov II comprise of species larger than Bov I and smaller than Impala *(Aepyceros melampus)*, and Bov III larger than Bov II and smaller than Roan *(Hippotragus equines)*. Bov IV consists of Buffalo *(Syncerus caffer)* and Eland *(Taurotragus oryx.)*

1.1.1 Observations of identifiable bones

To accurately process all the information possible from these fragments, a number of observations were noted on each specimen. This includes the establishment of the approximate age at which the individual died. This was done by different means, depending on which skeletal part of the skeleton survived.

The two methods used to determine age at death of faunal specimens are epiphyseal fusion, as well as dental eruption and tooth wear. Several different classes of tooth eruption and wear have been described for specific domestic [88,89] and wild animals [90]. Table 3.1 represents a summary, described by Plug, indicating the average age of an unknown mammalian individual according to its tooth morphology in the case of cranial fragments [91].

TABLE 3.1: Tooth eruption times and tooth wear [91]

Age class	Relative Age	Description
Class I	Foetal	Deciduous teeth not erupted
Class II	Neonate	Deciduous teeth not in wear
Class III	Juvenile	M1 in wear, M2 erupting
Class IV	Sub-adult	Loss of deciduous incisors and premolars, M3 erupting
Class V	Adult	Full permanent dentition present and in wear
Class VI	Mature	Central islands disappearing on M1 and M2
Class VII	Aged	Central islands disappearing on all teeth, M1 and M2 worn to gumline

Age determination on post-cranial fragments, for example long bones, is based upon epiphyseal fusion. Three broad categories are described for an unknown mammalian individual: a) A juvenile individual will be represented by long bones characterized by separate epi- and diaphyses, because the bones have not yet fully fused. b) A sub-adult individual will be characterized by long bones which are not yet fully fused. In this case an epiphyseal line will still be visible. c) In an adult the long bones will be completely fused [3,4].

The age of the individual may provide information about the taphonomy of the cave. Taphonomy, the study of how bones came to be buried and preserved, also includes observations about the condition of the bone. Descriptions of conditions or modifications such as gnaw marks may lead to identification of the chief accumulating agent, which in turn shed light on the taphonomy. Other conditions, such as specimens being modern or fossilized, burnt or weathered were also noted.

1.1.2 Measurement of identifiable bones

Measurements are fundamental tools of information which enhance the analysis of the skeletal material collected at the site. Measurements indicate the size of the fragments, which are used in several studies such as percentage survival rate of skeletal parts, taphonomy of the cave as well as identifying the chief accumulating agent. The equipment used included an electronic sliding caliper, spreading caliper, metal measuring tape, osteometric board and an electronic scale provided by the National Flagship Institution, University of Pretoria and Witwatersrand Technikon.

Measurements used were defined by Von den Driesch [72] and Peters [92]. These measurements were mostly done only when the bone was complete. An incomplete identifiable bone specimen was normally measured only in length, as specific structures needed for measurements were fragmented. More detail on bone measurements are described in Stage 2. All identifiable specimens were weighed. The specimen was then sealed for future study.

1.2 Non-identifiable bones

Specimens that were impossible to identify because of its small size or for any other reason, were catalogued as unidentifiable bones. These were placed in the following categories for statistical use [28]:

❶ Enamel fragments

All tooth and enamel fragments that could not be more specifically identified .

❷ Skull fragments

All fragments of the skull too small for identification.

❸ Vertebra fragments

This included all vertebrae.

❹ Rib fragments

All rib specimens, complete or not.

❺ Miscellaneous

All fragments too small to even determine from which area of the skeleton it originated. Thus it was fragmented beyond any recognition.

❻ Bone flakes

This included mostly long bone fragments that could not be identified as belonging to a specific major limb and which did not retain any articular surfaces.

All non-identifiable material were counted, weighed, documented in tables and sealed. All the faunal remains were already numbered according to the year it was excavated. Colour coding was used to accommodate easy future reference.

Prior to analysis a preliminary species list was compiled using Smithers [51] and du Plessis [50], as well as a faunal list which was acquired from the Ngonyama Game Reserve (Table 2.2). These were used to ascertain which species occurred in this area in the past, and which species are currently found in this area. The faunal list from the Game reserve was also used for interpretation of more recent, modern remains which could have been introduced by the reserve.

2. STAGE 2 - OSTEOMETRY

Stage 2 comprised of the determination of measurements which might enable morphological skeletal identification by means statistical analysis with the use of a computer programme. It involved the measuring of modern material, data capturing of the measurement values on a data base and the development of a computer program to classify and identify faunal remains using the measurements.

2.1 Measurements

As this is only a test to assess whether a data base programme will be able to identify and classify skeletal material, only the long bones of the hind limbs of all Southern African Bovid species were utilized to test the viability of classification of bones using osteometric values through computerized programmes. The 34 Southern African species available in South African museums, which represent the respective Bovid size classes I -IV and their average weight defined by Brain [87], are listed in Tables 3.2, 3.3, 3.4 and 3.5.

The modern collections used for this part of the study were kindly made available by the NFI (the former Transvaal Museum Pretoria), National Museum

(Bloemfontein) and the South African Museum (Cape Town). These three museums have the largest mammalian skeletal collections in South Africa. The bones were of known animals. Although all attempts were made to collect as many specimens for measurement purposes as possible, four species were unfortunately not represented in these Southern African modern collections and no measurements could be recorded for Dik-Dik (*Madoqua kirkii*), Sharp's Grysbok (*Raphicerus sharpei*), Puku (*Kobus vardonii*) and Lichtensteins Hartebeest (*Sigmoceros lichtensteinii*). Not all species are adequately represented in the modern skeletal collection, thus although sample sizes of thirty were preferred, some species are represented by less than this amount. Measurements defined by Von den Driesch [72], Peters [92] and Walker [93] were used. New measurements were also developed during the course of the study where necessary.

TABLE 3.2: Bovid size class I [91]

INDIVIDUAL		WEIGHT
Dik-Dik	*Madoqua kirkii*	4.5 - 5.0 kg
Suni	*Neutragus mosvhatis*	4.5 - 7.0 kg
Blue Duiker	*Philantomba monticola*	6.0 - 7.0 kg
Cape Grysbuck	*Raphicerus melanotis*	7.0 - 9.0 kg
Sharp's Grysbuck	*Raphicerus sharpei*	7.0 - 9.0 kg
Red Duiker	*Cephalophus natalensis*	9.0 - 14.0 kg
Klipspringer	*Oreotragus oreotragus*	10.0 - 16.0 kg
Steenbok	*Raphicems campaestris*	11.0 - 15.0 kg
Grey / Common Duiker	*Sylvicapra grimmia*	11.0 - 21.0 kg
Oribi	*Ourebia ourebi*	14.0 - 19.0 kg

TABLE 3.3: Bovid size class II [91]

INDIVIDUAL		WEIGHT
Springbuck	*Antidorcas marsupialis*	18.0 - 52.0 kg
Mountain Reedbuck	*Redunca fulvorufula*	23.0 - 27.0 kg
Grey Rhebuck	*Pelea caprelus*	23.0 - 27.0 kg
Bushbuck	*Tragelaphus scriptus*	23.0 - 83.0 kg
Blesbok	*Damaliscus dorcas philipsii*	32.0 - 81.0 kg
Impala	*Aepyceros melampus*	36.0 - 69.0 kg
Reedbuck	*Redunca arundinum*	34.0 - 104.0 kg
Puku	*Kobus vardonii*	56.0 - 84.0 kg
Sheep	*Ovis*	30.0 - 70.0 kg
Goat	Capra	25.0 - 60.0 kg

TABLE 3.4: Bovid size class III [91]

INDIVIDUAL		WEIGHT
Lechwe	*Kobus leche*	77.0 - 130.0 kg
Nyala	*Tragelaphus angasii*	91.0 - 114.0 kg
Sitatunga	*Tragelaphus spekei*	91.0 - 114.0 kg
Tsessebe	*Damaliscus lunatus*	117.0 - 158.0 kg
Red Hartebeest	*Alcelaphus buselaphus*	106.0 - 172.0 kg
Lichtenstein's Hartebeest	*Alcelaphus lichtensteinii*	146.0 - 205.0 kg
Kudu	*Tragelaphus strepsiceros*	150.0 - 296.0 kg
Black Wildebeest	*Connochaetes gnou*	158.0 - 182.0 kg
Waterbuck	*Kobus ellipsiprymnus*	158.0 - 272.0 kg
Gemsbok	*Oryx gazella*	182.0 - 238.0 kg
Sable	*Hippotragus niger*	205.0 - 264.0 kg
Blue Wildebeest	*Connochaetes taurinus*	205.0 - 274.0 kg
Roan	*Hippotragus equines*	223.0 - 299.0 kg
Domestic cattle	*Bos taurus*	160.0 - 190.0 kg

TABLE 3.5: Bovid size class IV [91]

INDIVIDUAL		WEIGHT
Eland	*Taurotragus oryx*	367.0 - 837.0 kg
Buffalo	*Syncerus caffer*	396.0 - 945.0 kg

The sex and origin of the individual were documented in cases where it was catalogued as such, although male and female data was pooled. 14 individual measurements were taken on each femur, 15 on the tibia and 16 on each metatarsal of the 30 bovid species. The left side was used in each case unless only the right side was available, in which case it was documented as being the right side.

The four basic types of measurements are as follows:

❶ **Breadth measurements:**

➘ Measurements from the most medial to the most lateral aspects.

➘ These are indicated in blue on all figures.

❷ **Depth measurements:**

➘ Measurements from the most anterior to the most posterior aspects.

➘ These are indicated in purple in all figures.

❸ **Length measurements:**

➘ Measurements from the most proximal to the most distal aspects.

➘ These are indicated in green in all figures.

❹ **Circumference measurements:**

➘ Measurements of the smallest circumference of the shaft.

➘ These are indicated in orange in all figures.

Measurements were done by the author only and repeated on different occasions. Aforementioned mechanisms were utilized to minimize investigator error.

An electronic calliper was mostly used. Although the electronic calliper provided readings up to three decimals (in mm), measurements used in statistical analyses were rounded off to the nearest two decimals. Other measuring equipment used included a spreading calliper, osteometric box and metal measuring tape. A metal measuring tape was chosen to eliminate stretching and therefore inaccurate measuring.

Tables 3.6 - 3.8 stipulate the measurements used in the study. It also gives the abbreviations that will be used when referring to a specific measurement for the remainder of the text. The measuring equipment used, as well as the source of the measurement are also tabulated. A colour coded key to the descriptions of the specific measurements can be seen in each table. Each measurement was given a new abbreviation for easier reference and comprised of the following:

Abbreviation for either femur, tibia or metatarsal
↑
F(GBP)
↓
Abbreviation for measurement taken

Figures 3.3a - 3.5b diagrammatically indicate the specific individual measurements done on the femur. Figures 3.6a -3.8 show measurements on the tibia and Figures 3.9a - 3.11a the metatarsal measurements. Information on how the measurements were taken are described in detail and accompany each figure. The original abbreviation of the measurements are listed with the figures for reference. The bones are illustrated from anterior, superior and inferior views to accommodate all measurement descriptions. Every view has a different figure number, but if it is used twice to accommodate all the measurements, an "a" or "b" indicate which measurements will be shown on the specific figure.

TABLE 3.6: Femur measurements

No	Abbr.	Description	Instrument	Fig
1	F(GL)◆	Greatest length.	Osteometric box	3.3a
2	F(GLH)◆	Greatest length from femur head.	Osteometric box	3.3a
3	F(SBD)◆	Smallest breadth of diaphyses.	Electronic calliper	3.3b
4	F(SCD)◆	Smallest circumference of diaphyses	Measuring tape	3.3b
5	F(GBP)◆●	Greatest breadth proximal end.	Electronic calliper	3.4
6	F(GDH)◆	Greatest depth femur head.	Electronic calliper	3.4
7	F(GBH)▮	Greatest breadth femur head.	Electronic calliper	3.4
8	F(GBD)◆●	Greatest breadth distal end.	Electronic calliper	3.5a
9	F(GLDD)✚	Greatest lateral depth distal end.	Electronic calliper	3.5a
10	F(GMDD)✚	Greatest medial depth distal end.	Electronic calliper	3.5a
11	F(GBCF)▮	Greatest breadth condylar fossa.	Electronic calliper	3.5b
12	F(SBCF)▮	Smallest breadth condylar fossa.	Electronic calliper	3.5b
13	F(GBT)✚	Greatest breadth trochlea.	Electronic calliper	3.5b
14	F(GL-GLH)▮	Greatest length-Greatest length from femur head.	Calculation	

◆ Measurements defined by Von den Driesch [72]

✚ Measurements defined by Peters [92]

● Measurements defined by Walker [93]

▮ *Measurements developed* by the author

TABLE 3.7: Tibia measurements

No	Abbr.	Description	Instrument	Fig
1	T(GL)◆●	Greatest length.	Osteometric box	3.6a
2	T(GML)▮	Greatest medial length.	Osteometric box	3.6a
3	T(GLL)◆	Greatest lateral length.	Osteometric box	3.6a
4	T(SBD)◆	Smallest breadth of diaphyses.	Electronic calliper	3.6b
5	T(SCD)◆	Smallest circumference of diaphyses	Measuring tape	3.6b
6	T(GBP)◆●	Greatest breadth proximal end.	Electronic calliper	3.7a
7	T(GDP)✚	Greatest depth proximal end.	Osteometric box	3.7a
8	T(GDLC)▮	Greatest depth lateral condyle.	Electronic calliper	3.7b
9	T(GDMC)▮	Greatest depth medial condyle.	Electronic calliper	3.7b
10	T(GDT)▮	Greatest depth tibial tuberosity.	Spreading calliper	3.7b
11	T(GDTN)▮	Greatest depth tibial tuberosity from notch.	Electronic calliper	3.7b
12	T(SBIE)▮	Smallest breadth intercondylar eminence.	Electronic calliper	3.7a
13	T(GBD)◆●	Greatest breadth distal end.	Electronic calliper	3.8
14	T(GDD)◆✚	Greatest depth distal end.	Electronic calliper	3.8
15	T(SDD)●	Smallest depth distal end.	Electronic calliper	3.8

◆ Measurements defined by Von den Driesch [72]

✚ Measurements defined by Peters [92]

● Measurements defined by Walker [93]

▮ Measurements developed by the author

TABLE 3.8: Metatarsal measurements

No	Abbr	Description	Instrument	Fig
1	M(GL)◆	Greatest length.	Osteometric box	3.9a
2	M(GML)▮	Greatest medial length.	Osteometric box	3.9a
3	M(GLL)◆	Greatest lateral length.	Osteometric box	3.9a
4	M(SBD)◆	Smallest breadth of diaphyses.	Electronic calliper	3.9b
5	M(SCD)◆	Smallest circumference of diaphyses	Measuring tape	3.9b
6	M(GBP)◆●	Greatest breadth proximal end.	Electronic calliper	3.10b
7	M(GDP)◆	Greatest depth proximal end.	Electronic calliper	3.10b
8	M(GLMA)▮	Greatest length medial articulation facet prox. end.	Electronic calliper	3.10a
9	M(GBMA)▮	Greatest breadth medial articulation facet prox. end.	Electronic calliper	3.10a
10	M(GLLA)▮	Greatest length lateral articulation facet prox. end.	Electronic calliper	3.10a
11	M(GBLA)▮	Greatest breadth lateral articulation facet prox. end.	Electronic calliper	3.10a
12	M(GBD)◆	Greatest breadth distal end.	Electronic calliper	3.11b
13	M(GDD)◆✚	Greatest depth distal end.	Electronic calliper	3.11b
14	M(GBMC)●	Greatest breadth medial condyle.	Electronic calliper	3.11a
15	M(GBLC)●	Greatest breadth lateral condyle.	Electronic calliper	3.11a
16	M(GBDE)▮	Greatest breadth distal eminences.	Electronic calliper	3.11a

◆ Measurements defined by Von den Driesch [72]

✚ Measurements defined by Peters [92]

● Measurements defined by Walker [93]

▮ Measurements developed by the author

2.1.1 Measurements on the femur

A) ANTERIOR VIEW OF THE FEMUR - FIGURE 3.3a

F(GL) = Greatest length.

➘ Original abbreviation: "GL" (Von den Driesch, 1976) [72]

The greatest distance from the proximal extremity to the distal extremity was measured. Important to note is that both femoral condyles should be in the same vertical plane. Thus both condyles should be in contact with the vertical part of the osteometric box, with the posterior aspect closest to the floor of the box. The femur should therefore be placed at an angle to the horizontal line of the box.

F(GLH) = Greatest length from femur head.

➘ Original abbreviation: "GLC" (Von den Driesch, 1976) [72]

The greatest distance from the head of the femur to the distal extremity was measured. The femur must be placed in the same position as with the F(GL) measurement. Thus both condyles should be in contact with the vertical part of the osteometric board. The F(GLH) was on average less than the F(GL).

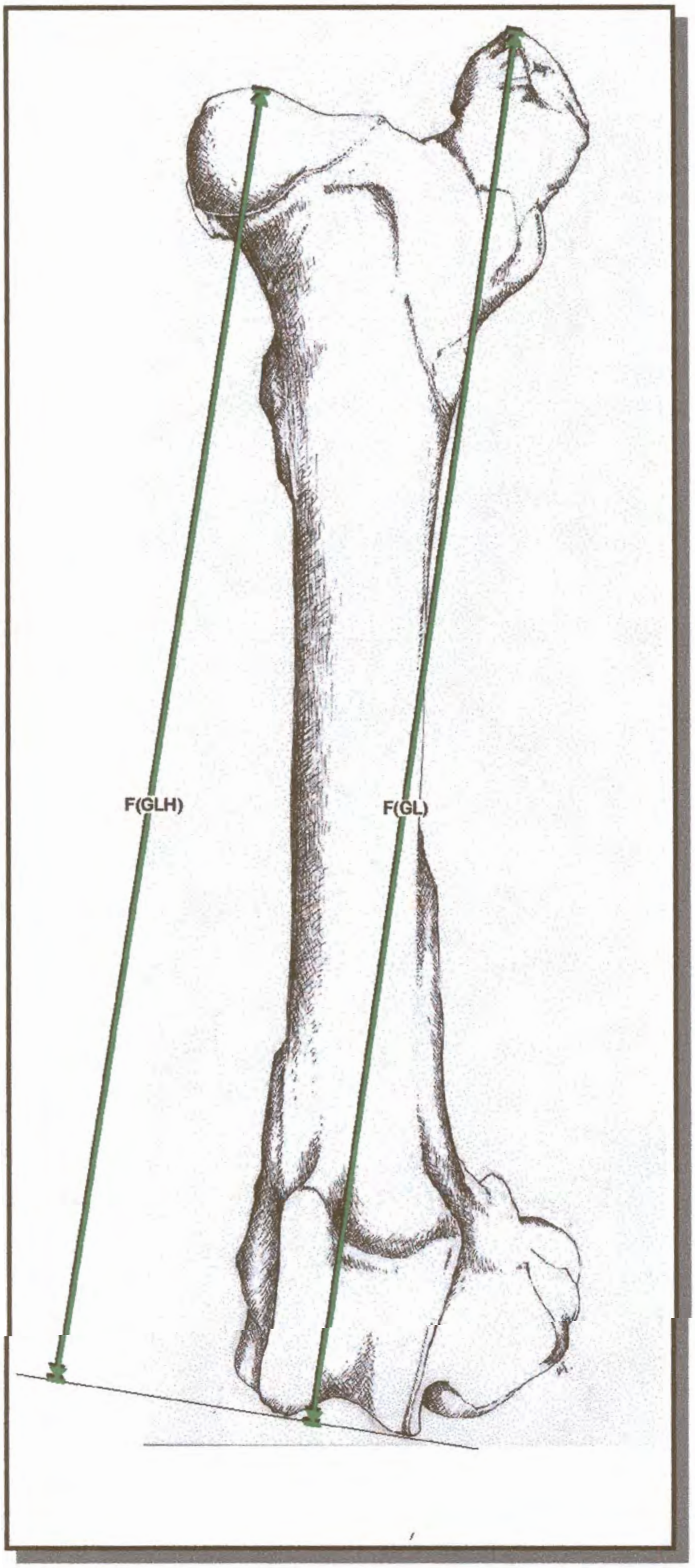


FIGURE 3.3a: Femur:
Anterior view
F(GL)
F(GLH)

A) ANTERIOR VIEW OF THE FEMUR - FIGURE 3.3b

F(SBD) = Smallest breadth of diaphyses.

➘ Original abbreviation: "SD" (Von den Driesch, 1976) [72]

The smallest breadth on the shaft of the femur was taken. The femur should be placed in the same position as for F(GL). The jaws of the calliper should be placed to the lateral and medial aspects of the shaft, and moved proximally and distally to ascertain the smallest measurement. This measurement was on average taken approximately in the middle of the femur shaft.

F(SCD) = Smallest circumference of diaphyses.

➘ Original abbreviation: "CD" (Von den Driesch, 1976) [72]

The smallest circumference of the shaft of the femur was taken with a metal measuring tape. The measuring tape must be moved proximally and distally to establish the smallest reading.

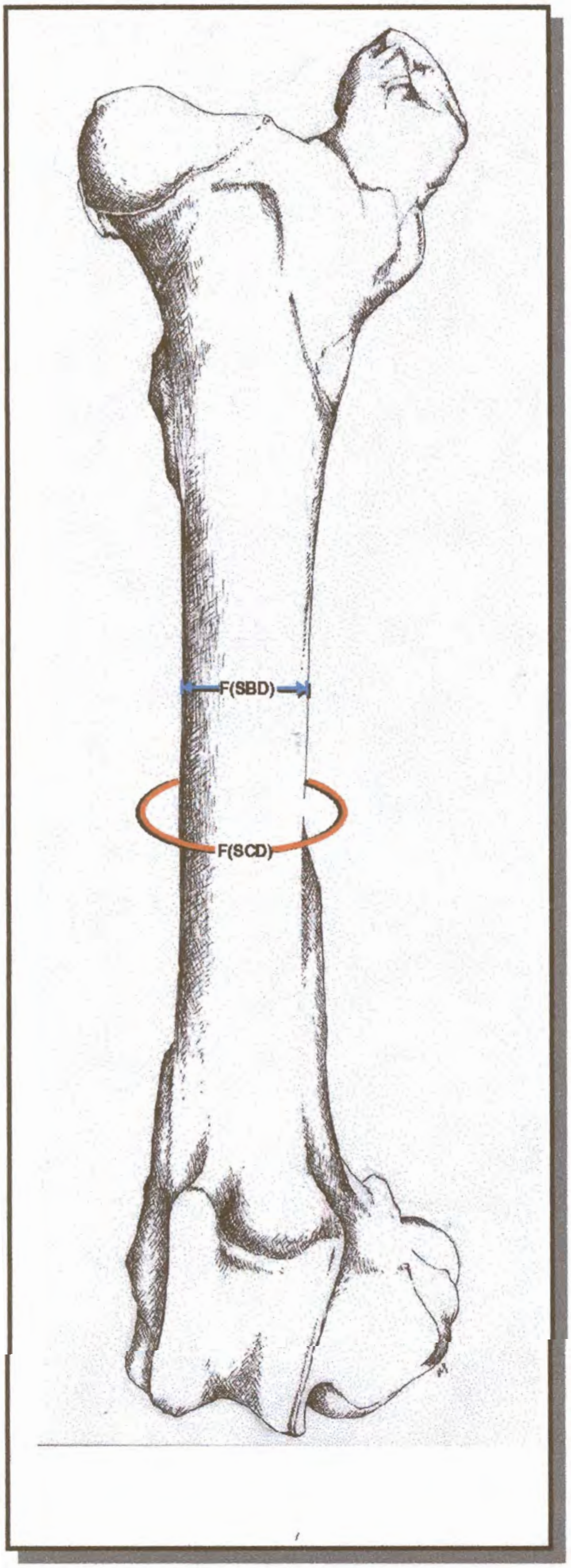


FIGURE 3.3b: Femur :
Anterior view
F(SBD)
F(SCD)

B) SUPERIOR VIEW OF THE FEMUR - FIGURE 3.4.

F(GBP) = Greatest breadth proximal end.

➘ Original abbreviation: "Bp" (Von den Driesch, 1976) [72]

"A" (Walker, 1985) [93]

The greatest breadth of the proximal end of the femur extends from the most lateral point of the greater trochanter to the most medial point of the head of the femur. This measurement was taken with a sliding calliper.

F(GBH) = Greatest breadth femur head.

➘ Developed by author

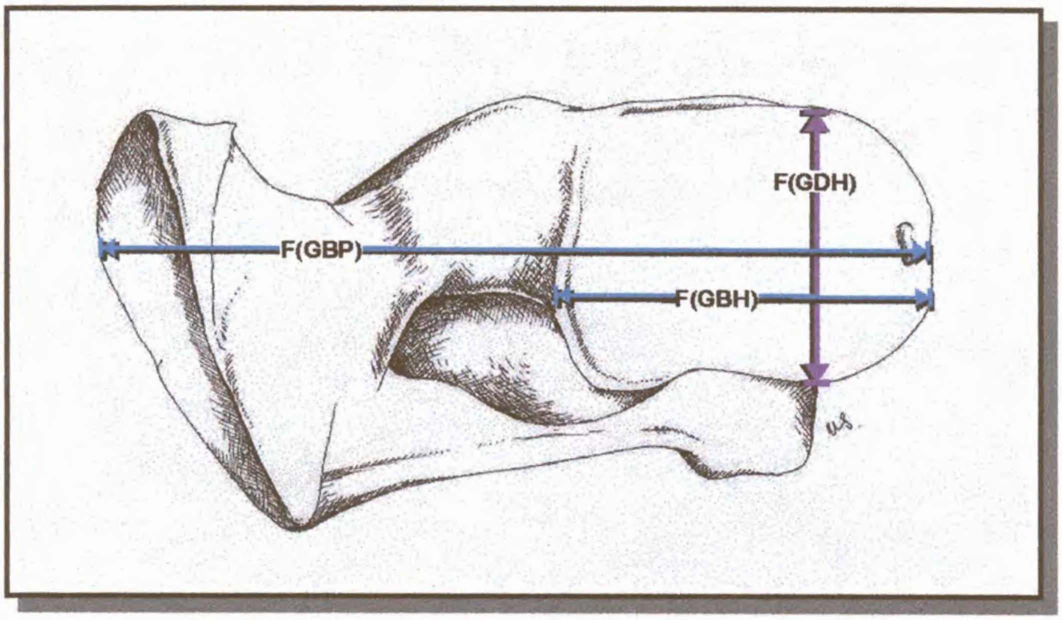
This measurement was taken with a sliding calliper and measured the breadth of the femur head. This is a fairly easy measurement as the borders of the head are usually distinct.

F(GDH) = Greatest depth femur head.

➘ Original abbreviation: "DC" (Von den Driesch, 1976) [72]

The greatest depth of the femur head is measured from anterior to posterior with a sliding calliper. The measurement should be taken perpendicular to F(GBH). The femur should be held with the superior aspect facing the measurer, as this ensures accuracy.

FIGURE 3.4: Femur: Superior view F(GBP) ; F(GBH) ; F(GDH)



C) INFERIOR VIEW OF THE FEMUR - FIGURE 3.5a.

F(GBD) = Greatest breadth distal end.

➘ Original abbreviation: "Bd" (Von den Driesch, 1976) [72]

"A" (Walker, 1985) [93]

The greatest breadth from the most lateral point to the most medial point on the distal end of the femur is measured with a sliding calliper. In some cases, for example Bov IV size specimens, an osteometric board may be used due to the size of the bone.

F(GLDD) = Greatest lateral depth distal end.

➘ Original abbreviation: "Dld" (Peters, 1985) [92]

The greatest lateral depth of the distal end of the femur is more easily measured from the lateral view. This measurement is taken with a sliding calliper from the most anterior point to the most posterior point of the lateral femoral condyle.

F(GMDD) = Greatest medial depth distal end.

➘ Original abbreviation: "Dmd" (Peters, 1985) [92]

The greatest medial depth of the distal end of the femur is also taken with a sliding calliper. This measurement is taken from the most anterior to the most posterior point of the medial femoral condyle and is more accurate if taken from a medial view of the femur.

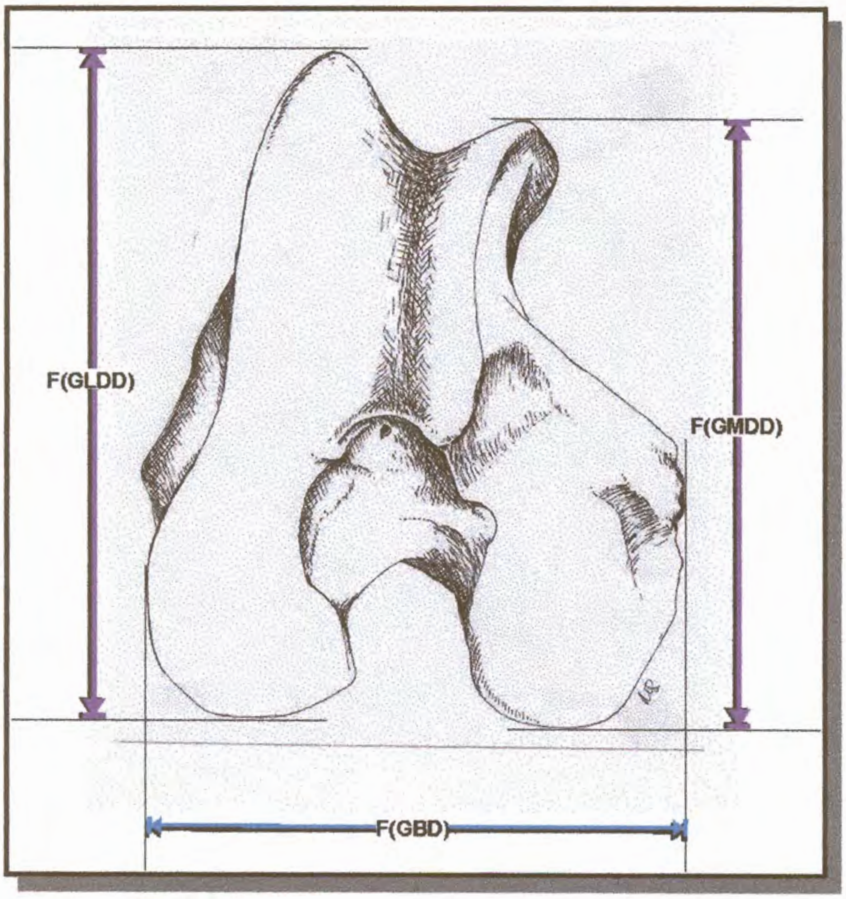


FIGURE 3.5a:
Femur:
Inferior view
F(GBD)
F(GLDD)
F(GMDD)

C) INFERIOR VIEW OF THE FEMUR - FIGURE 3.5b.

F(GBT) = Greatest breadth trochlea.

↘ Original abbreviation: "BT" (Peters, 1985) [92]

The greatest breadth of the trochlea of the femur should be measured at the same angle as the trochlea itself. The measurement must therefore be taken in line with the trochlea from the most medial to the most lateral point. A sliding calliper is used to take the measurement.

F(GBCF) = Greatest breadth condylar fossa.

↘ Developed by author

The greatest breadth of the condylar fossa of the femur is a fairly difficult measurement as the landmarks differ in every individual. In some cases it was covered with osteophytes and the actual measurement was sometimes difficult to ascertain. The sharp outer jaws of the calliper were used to measure the greatest distance in between the two femoral condyles.

F(SBCF) = Smallest breadth condylar fossa.

↘ Developed by author

The smallest breadth of the condylar fossa was also measured with the outer sharp jaws of the calliper. The smallest distance between the femoral condyles was measured. Occasionally the F(GBCF) and F(SBCF) were equal in value.

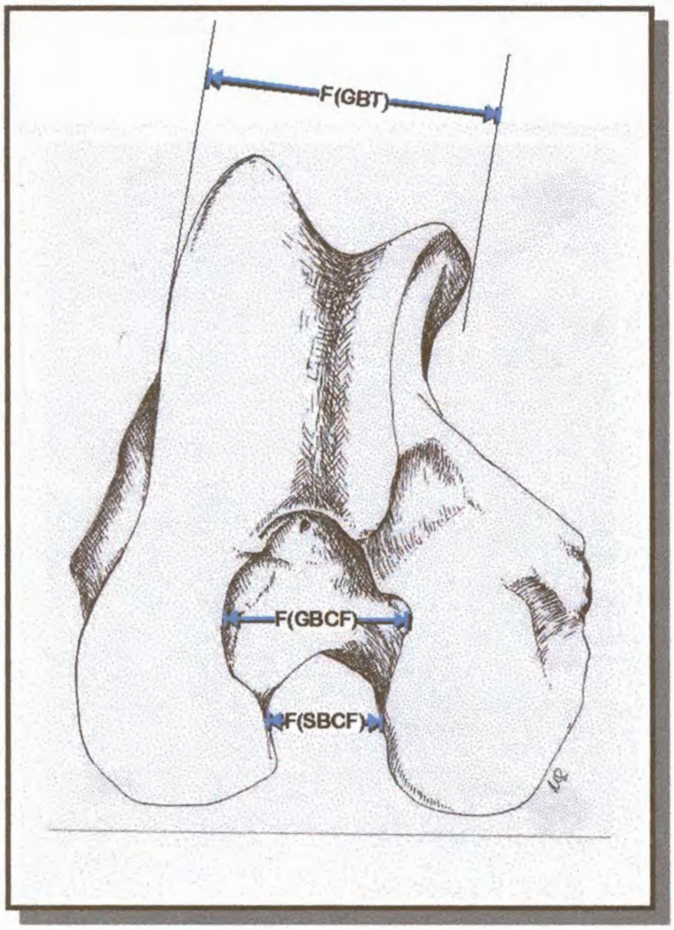


FIGURE 3.5b: Femur:
Inferior view
F(GBT)
F(GBCF)
F(SBCF)

2.1.2 Measurements on the tibia

A) ANTERIOR VIEW OF THE TIBIA - FIGURE 3.6a

T(GL) = Greatest length.

↘ Original abbreviation: "GL" (Von den Driesch, 1976) [72]

"C" (Walker, 1985) [93]

The greatest distance from the proximal extremity to the distal extremity was measured. Important to note is that the tibia should be placed at the same angle as the osteometric box. Thus it should be positioned with its long axis perpendicular to that of the horizontal part of the osteometric box.

T(GLL) = Greatest lateral length.

↘ Original abbreviation: "Ll" (Von den Driesch, 1976) [72]

The greatest distance from the most superior point of the lateral tibial condyle to the most inferior point on the distal extremity was measured. The tibia must be placed in the same position as with the T(GL) measurement.

T(GML) = Greatest medial length.

↘ Developed by the author

The greatest distance from the most superior point of the medial tibial condyle to the most inferior point on the distal extremity was measured. Again the tibia must remain in the same position as with the T(GL) measurement.

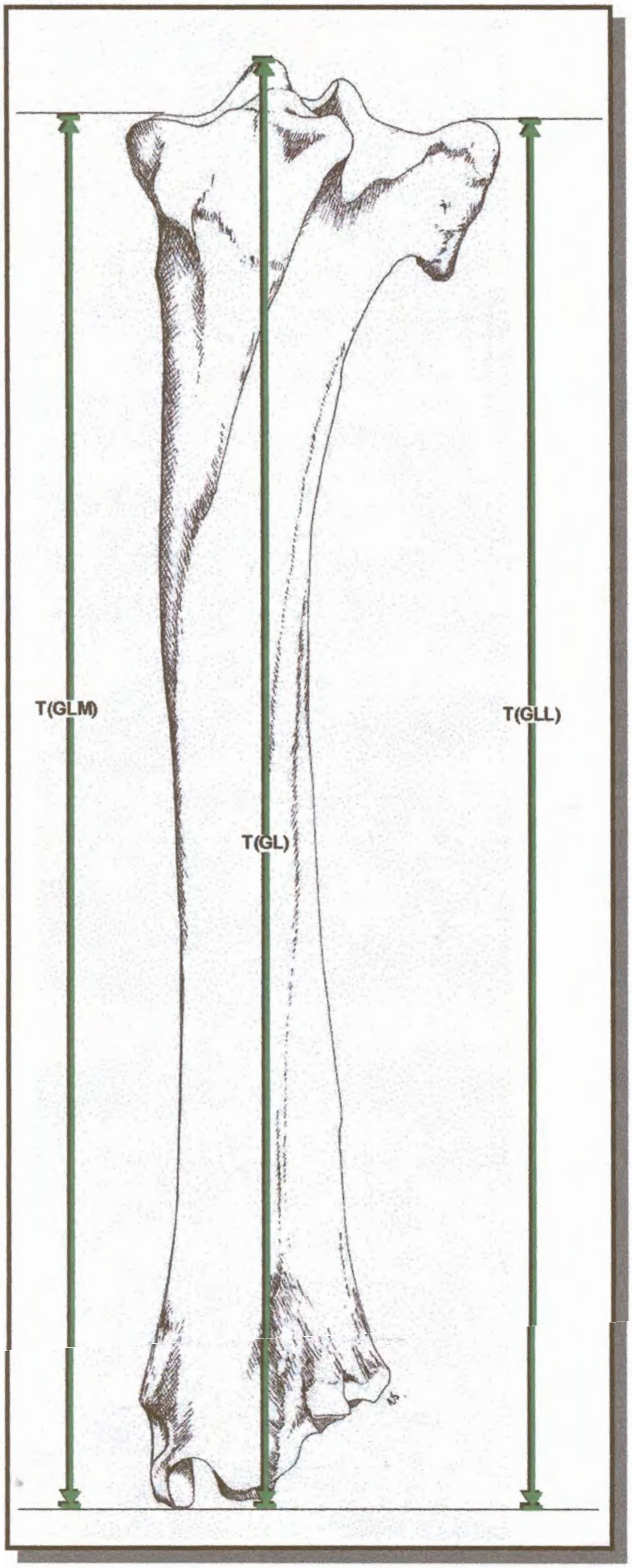


FIGURE 3.6a: Tibia:
Anterior view
T(GL)
T(GLL)
T(GLM)

A) ANTERIOR VIEW OF THE TIBIA - FIGURE 3.6b

T(SBD) = Smallest breadth of diaphyses.

➘ Original abbreviation: "SD" (Von den Driesch, 1976) [72]

The smallest diameter was taken on the breadth of the tibial shaft. The tibia should be placed in the same position as for T(GL). The jaws of the calliper should be placed on the lateral and medial apects of the shaft, and moved proximally and distally to ascertain the smallest measurement. This measurement was on average taken on the distal third of the tibial shaft.

T(SCD) = Smallest circumference of diaphyses.

➘ Original abbreviation: "CD" (Von den Driesch, 1976) [72]

The smallest circumference of the shaft of the tibia was taken with a metal measuring tape. The measuring tape must be moved proximally and distally to establish the smallest reading.

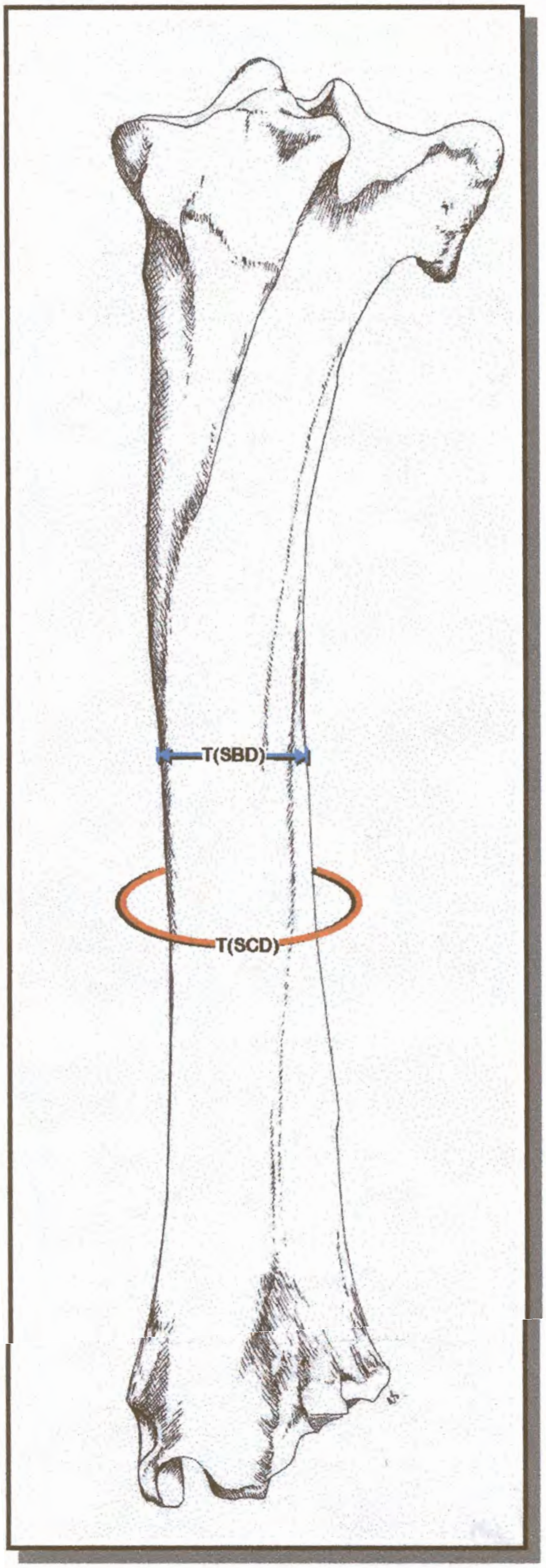


FIGURE 3.6b: Tibia:
Anterior view
T(SBD)
T(SCD)

B) SUPERIOR VIEW OF THE TIBIA - FIGURE 3.7a

T(GBP) = Greatest breadth proximal end.

➘ Original abbreviation: "Bp" (Von den Driesch, 1976) [72]

"A" (Walker, 1985) [93]

The greatest breadth of the proximal end of the tibia was measured from the most medial to the most lateral aspects of this end. The measurement is done using a sliding calliper.

T(GDP) = Greatest depth proximal end.

➘ Original abbreviation: "Dp" (Peters, 1985) [92]

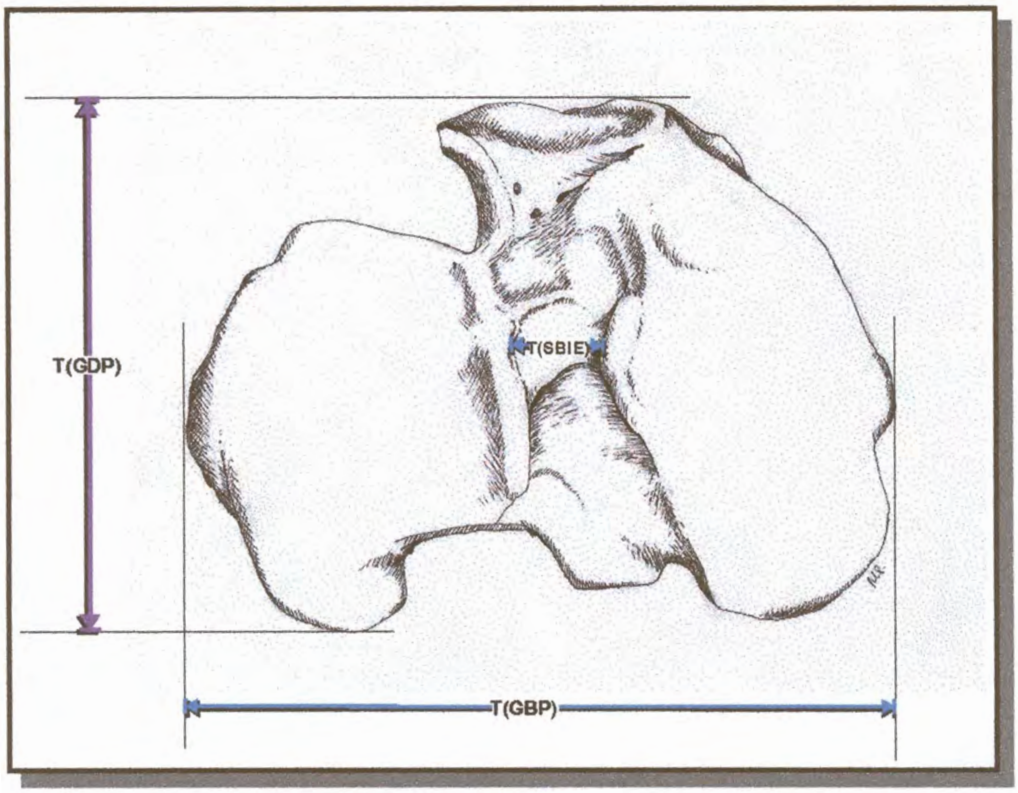
The greatest depth of the proximal end was measured in an osteometric box. This was done to ensure the accuracy of the measurement. The superior aspect of the tibia was placed so that it was in contact with the osteometric box. It was held at a right angle to the floor of the box. The greatest distance between the most anterior and posterior aspects of the proximal end was measured.

T(SBIE) = Smallest breadth intercondylar eminence.

➘ Developed by author

The smallest distance between the medial and lateral intercondyler eminences was measured with a sliding calliper.

FIGURE 3.7a: Tibia: Superior view T(GDP) ; T(GBP) ; T(SBIE)



B) SUPERIOR VIEW OF THE TIBIA - FIGURE 3.7b

T(GDLC) = Greatest depth lateral condyle.

➘ Developed by author

The greatest depth of the lateral condyle was measured. The greatest distance from the most anterior to the most posterior point on the lateral condyle of the tibia was measured with a sliding calliper. The borders of the lateral condyle are clearly defined.

T(GDMC) = Greatest depth medial condyle.

➘ Developed by the author

The greatest depth of the medial condyle was measured. The greatest distance from the most anterior to the most posterior point on the medial condyle of the tibia was measured with a sliding calliper. This measurement was sometimes difficult, since the anterior border of the condyle is not always clear. If it was unclear, the anterior border of the smooth articulation surface was taken as the most anterior point.

B) SUPERIOR VIEW OF THE TIBIA - FIGURE 3.7b Continue

T(GDT) = Greatest depth tibial tuberosity.

➘ Developed by the author

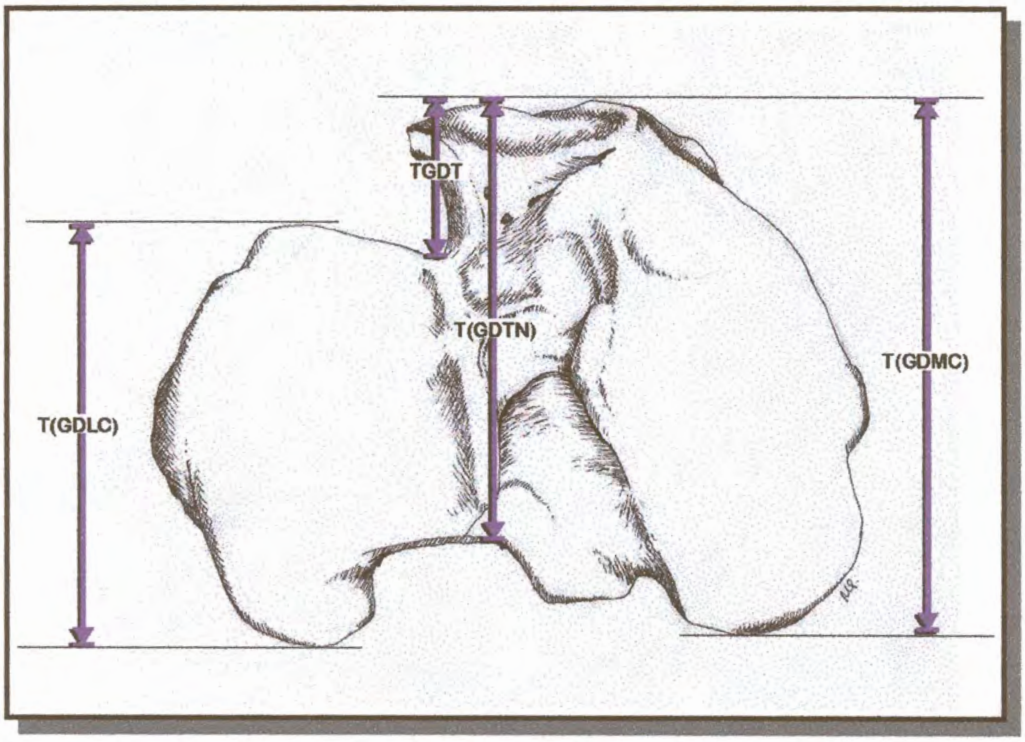
The greatest depth of the tibial tuberosity was measured with the outer sharp jaws of the sliding calliper. This measurement was not always accurate, since there are no clearly defined points where the jaws of the calliper should be placed to enable measuring.

T(GDTN) = Greatest depth tibial tuberosity from notch.

➘ Developed by the author

This measurement was done using a spreading calliper. The two jaws of the calliper were placed in contact with the tibial tuberosity anteriorly and tibial notch posteriorly respectively, to measure the greatest distance between the two points.

FIGURE 3.7b: Tibia: Superior view T(GDLC) ; T(GDMC) ; T(GDT) ; T(GDTN)



C) INFERIOR VIEW OF THE TIBIA - FIGURE 3.8

T(GBD) = Greatest breadth distal end.

➘ Original abbreviation: "Bd" (Von den Driesch, 1976) [72]

"A" (Walker, 1985) [93]

The greatest breadth of the distal end of the tibia was measured with a sliding calliper from the most medial point to the most lateral point.

T(GDD) = Greatest depth distal end.

➘ Original abbreviation: "Dd" (Von den Driesch, 1976) [72]

"Dd" (Peters, 1985) [92]

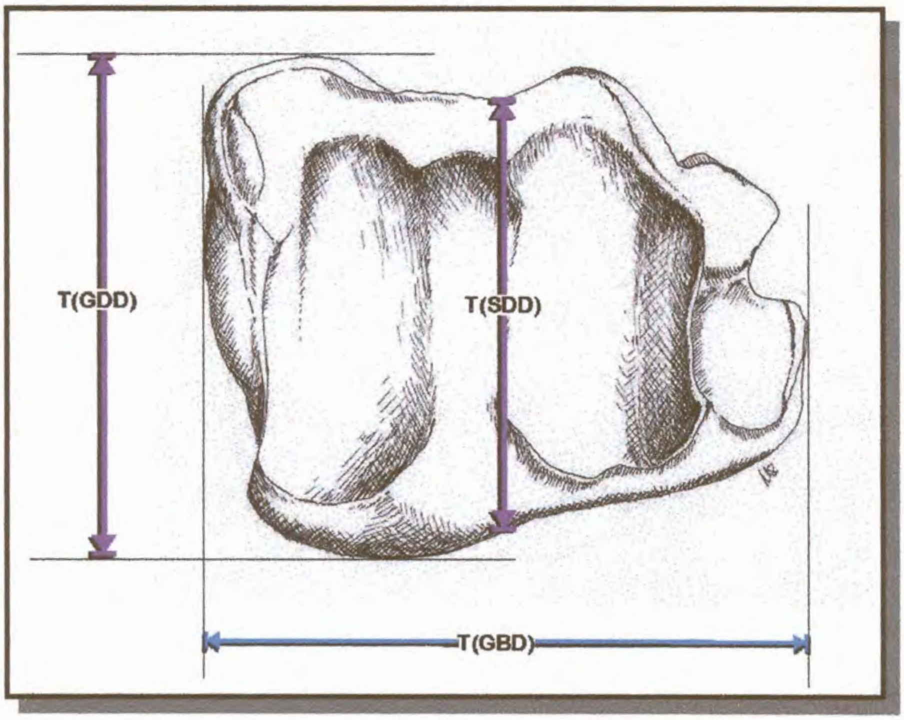
The greatest distance from the most anterior to the most posterior point of the distal end was measured with a sliding calliper.

T(SDD) = Smallest depth distal end.

➘ Original abbreviation: "B" (Walker, 1985) [93]

The smallest depth of the distal end of the tibia was measured with a sliding calliper. The measurement was mostly taken approximately between the two articulating facets for the tarsal bones.

FIGURE 3.8: Tibia: Inferior view T(GDD) ; T(GBD) ; T(SDD)



2.1.3 Measurements on the metatarsal

A) ANTERIOR VIEW OF THE METATARSAL - FIGURE 3.9a

M(GL) = Greatest length.

- Original abbreviation: "GL" (Von den Driesch, 1976) [72]

The greatest distance from the most superior point on the proximal extremity to the most inferior point on the distal extremity was measured. It is important to note that the metatarsal should be placed at the same plane as the osteometric box. The shaft should be positioned perpendicular to the horizontal part of the osteometric box.

M(GLL) = Greatest lateral length.

- Original abbreviation: "GLl" (Von den Driesch, 1976) [72]

The greatest distance from the most superior point on the proximal end to the most inferior point of the lateral condyle of the metatarsal was measured. The metatarsal must be placed in the same position as with the M(GL) measurement. This measurement was done by means of an osteometric box.

M(GML) = Greatest medial length.

- Developed by the author

The greatest distance from the most superior point of the proximal end to the inferior point of the medial condyle of the metatarsal was measured. The metatarsal must remain in the same position as with the M(GL) measurement.

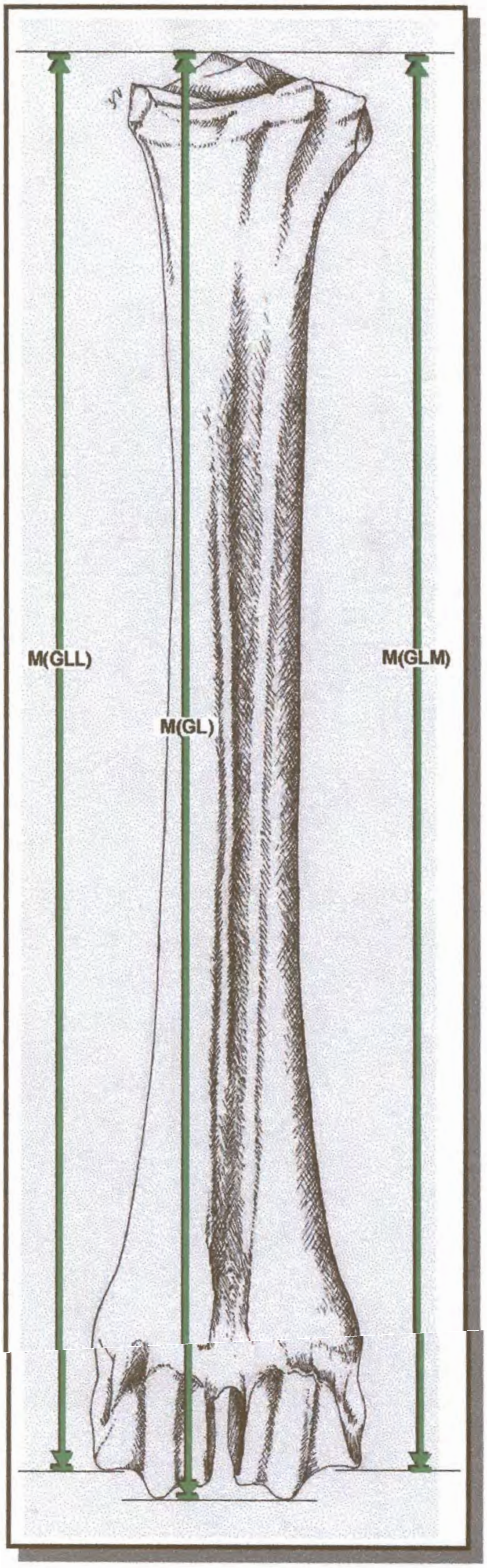


FIGURE 3.9a: Metatarsal:
Anterior view
M(GL)
M(GLM)
M(GLL)

A) ANTERIOR VIEW OF THE METATARSAL - FIGURE 3.9b

M(SBD) = Smallest breadth of diaphyses.

➘ Original abbreviation: "SD" (Von den Driesch, 1976) [72]

The smallest diameter taken on the breadth of the metatarsal shaft. The metatarsal should be placed in the same position as for M(GL). The jaws of the calliper should be placed to the lateral and medial aspects of the shaft, and moved proximally and distally to ascertain the smallest measurement. This measurement was taken on average near the middle of the shaft.

M(SCD) = Smallest circumference of diaphyses.

➘ Original abbreviation: "CD" (Von den Driesch, 1976) [72]

The smallest circumference of the shaft of the metatarsal was taken with a metal measuring tape. The measuring tape must be moved proximally and distally to establish the smallest reading. Usually this measurement was taken on the distal third of the shaft.

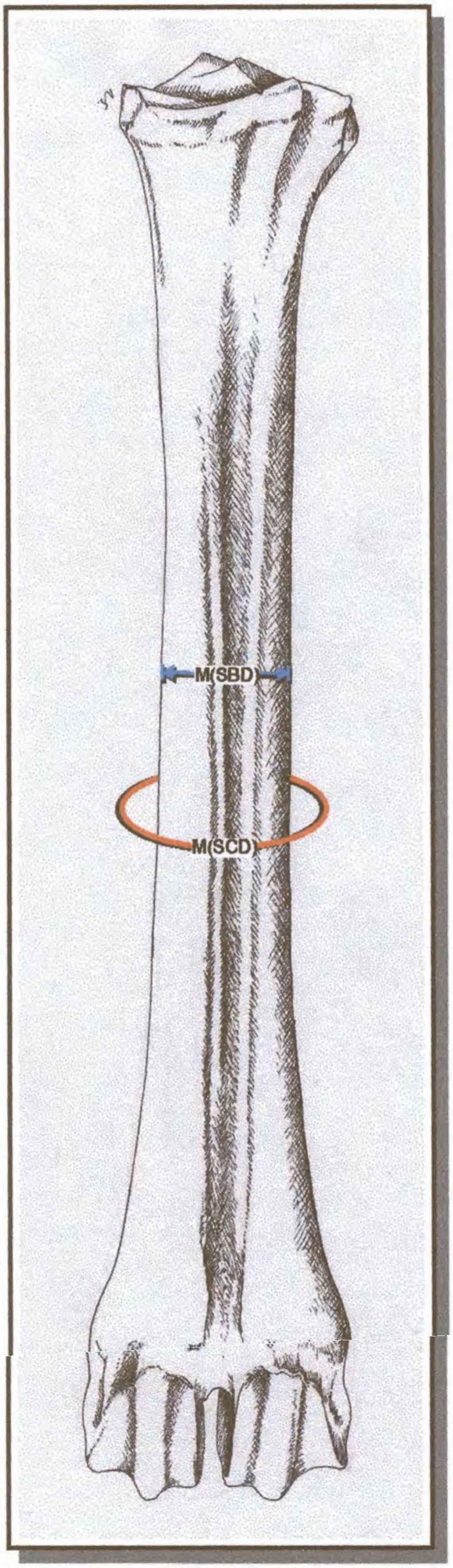


FIGURE 3.9b: Metatarsal:
Anterior view
M(SCD)
M(SBD)

B) SUPERIOR VIEW OF THE METATARSAL - FIGURE 3.10a

All of the measurements described below were uncomplicated since the borders of the articulating facets were well defined on most specimens.

M(GLLA) = Greatest length lateral articulating facet on proximal end.

➘ Developed by the author

The greatest length of the lateral articulation facet was measured with a sliding calliper.

M(GBLA) = Greatest breadth lateral articulating facet on proximal end.

➘ Developed by the author

The greatest breadth of the lateral articulating facet was measured. It is important to note that this measurement should be at a right angle to M(GLLA).

M(GLMA) = Greatest length medial articulating facet on proximal end.

➘ Developed by the author

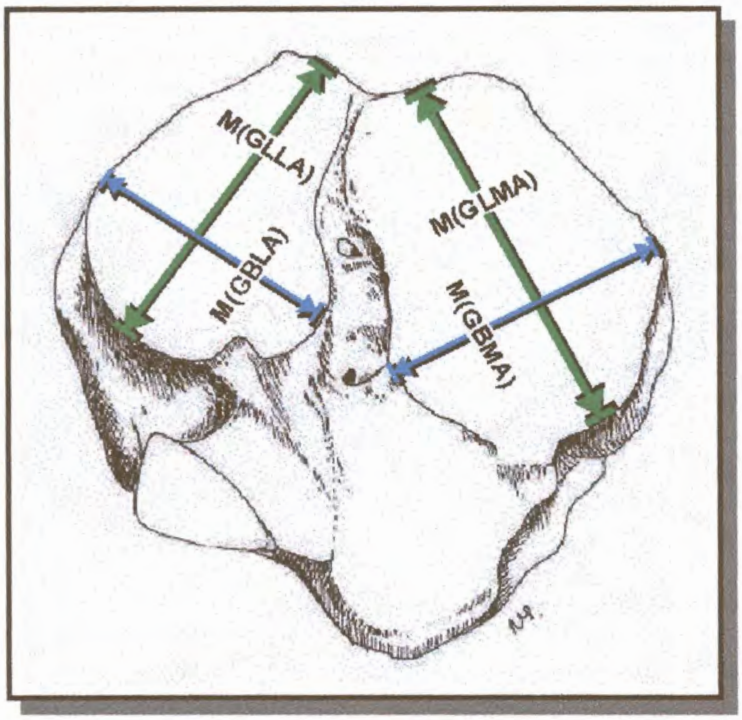
The greatest length of the medial articulating facet was measured.

M(GBMA) = Greatest breadth medial articulating facet on proximal end.

➘ Developed by the author

The greatest breadth of the medial articulating facet was measured. Again it is important to note that this measurement should be at a right angle to measurement M(GLMA).

FIGURE 3.10a: Metatarsal: Superior view M(GLLA) ; M(GBLA) ; M(GLMA) ; M(GBMA)



B) SUPERIOR VIEW OF THE METATARSAL - FIGURE 3.10b

M(GBP) = Greatest breadth proximal end.

➘ Original abbreviation: "Bp" (Von den Driesch, 1976) [72]

"C" (Walker, 1985) [93]

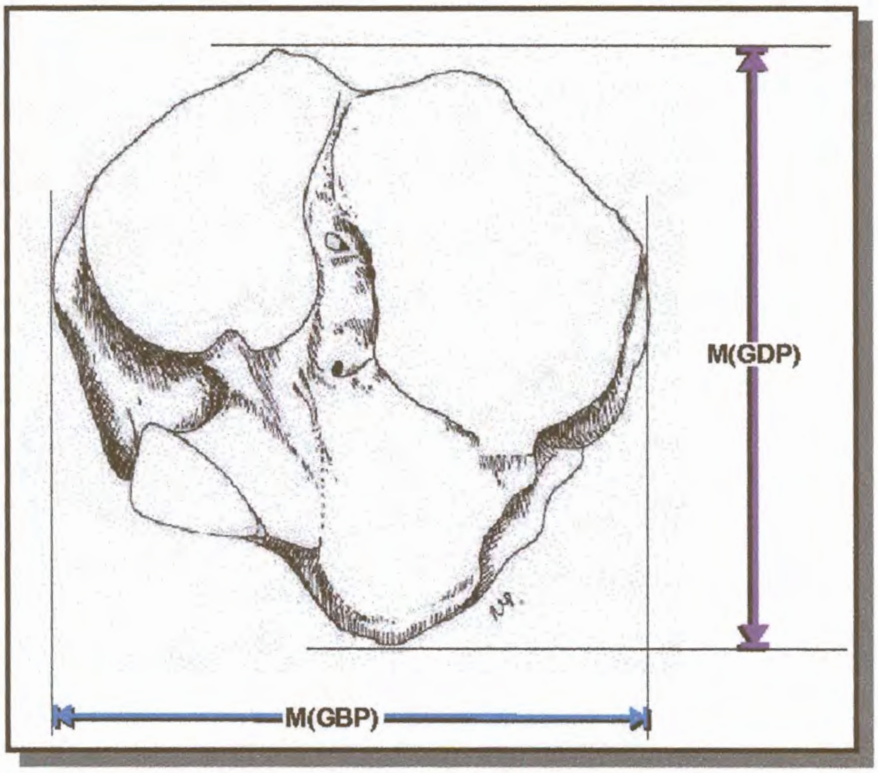
The greatest breadth is measured from the most lateral to the most medial points of the proximal end of the metatarsal with a sliding calliper.

M(GDP) = Greatest depth proximal end.

➘ Original abbreviation: "Dp" (Von den Driesch, 1976) [72]

The greatest depth was measured from the most anterior to the most posterior point on the proximal end of the metatarsal with a sliding calliper.

FIGURE 3.10b: Metatarsal: Superior view M(GDP) ; M(GBP)



C) INFERIOR VIEW OF THE METATARSAL - FIGURE 3.11a

M(GBDE) = Greatest breadth distal eminences.

➘ Developed by the author

The greatest breadth between the outsides of the medial and lateral distal eminences was measured with the outer sharp jaws of a sliding calliper to ensure an accurate measurement. Ii is important to note is that this measurement was taken on the most inferior point of the distal end.

M(GBLC) = Greatest breadth lateral condyle.

➘ Original abbreviation: "B" (Walker, 1985) [93]

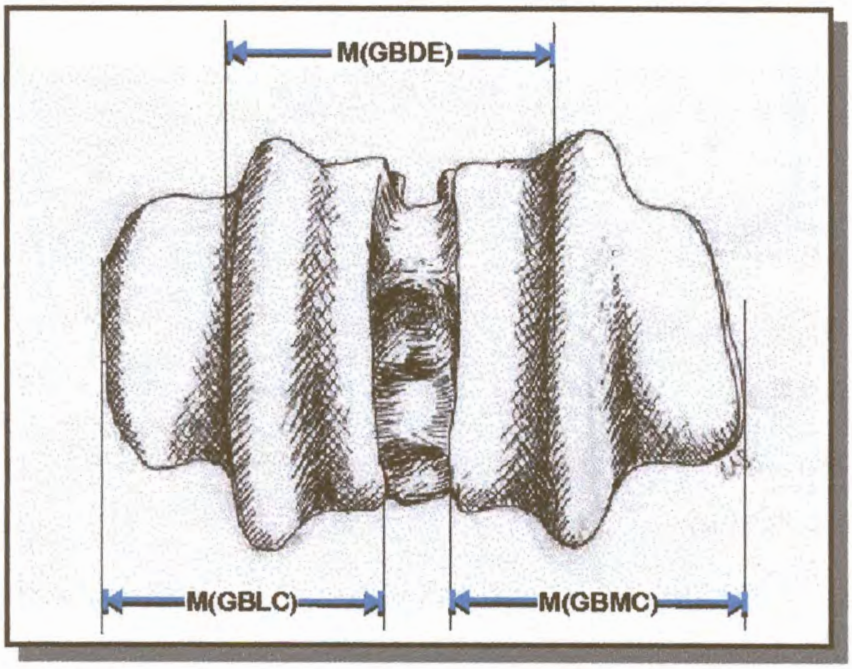
The greatest distance between the most lateral and the most medial point of the lateral condyle of the metatarsal was measured. The measurement was taken from anterior with a sliding calliper.

M(GBMC) = Greatest breadth medial condyle.

➘ Original abbreviation: "D" (Walker, 1985) [93]

The greatest distance between the most lateral and the most medial point of the medial condyle of the metatarsal was measured. The measurement was taken from anterior with a sliding calliper.

FIGURE 3.11a: Metatarsal: Inferior view M(GBDE) ; M(GBLC) ; M(GBMC)



C) INFERIOR VIEW OF THE METATARSAL - FIGURE 3.11b

M(GBD) = Greatest breadth distal end.

➘ Original abbreviation: "Bd" (Von den Driesch, 1976) [72]

The greatest distance from the most medial to the most lateral points on the distal end of the metatarsal was measured with a sliding calliper. It is important to note that the jaws of the calliper should be in line with the distal eminences of the metatarsal.

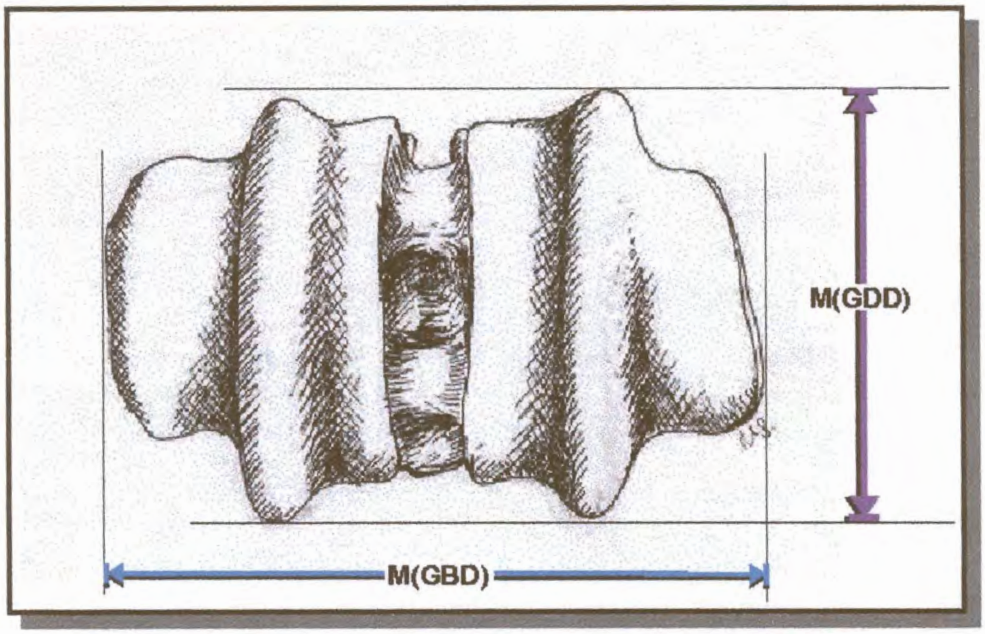
M(GDD) = Greatest depth distal end.

➘ Original abbreviation: "Dd" (Von den Driesch, 1976) [72]

"Dd" (Peters, 1985) [92]

The greatest distance from the most anterior to the most posterior points on the distal end of the metatarsal was measured with a sliding calliper. The jaws of the calliper should be at a right angle to the distal eminences of the metatarsal.

FIGURE 3.11b: Metatarsal: Inferior view M(GBD) ; M(GDD)



2.2 Data collection and statistical analysis

Measurements were entered into a database and a variety of calculations were done. These included minimum and maximum values, standard deviations as well as medians and means.

Males and females were not separated in the calculations performed on the data, since the sample sizes of most of these species were inadequate. Another reason for the combination was that a large amount of the specimens measured at the different museums were not identified as being either male or female. Further studies on more extensive collections may create large enough sample sizes to separate the specimens according to sex. The sex of each specimen was, however, noted where available.

Research has shown that differences in skeletal morphology exist between animals that are born in the wild and those born in captivity. Again, this information was lacking in most of the specimens measured. Zoo and wild born specimens were not statistically differentiated, but was, however, noted as being one or the other where data was available.

An index is a percentage value that describes measurements in relation to each other. By using indices, size factors are nullified, while shape becomes more important. The indices in this study are mainly used to determine the specimen's circumference in relation to its length. Therefore they give an indication of the robusticity of the bone.

The statistical program Sigmastat was used to establish whether a significant difference between the means of the individual Bovid class measurements exists.

Students t-tests were done to establish whether a significant difference occurs between the individual measurements within the bovid size classes. Every bovid species within a size class was statistically tested against the average of all the other species within the same bovid size class. It was therefore established whether one species in a size class differs to such an extent that it would be positively identified if compared to the species within the same bovid size class.

The data was entered into Lotus Smartsuite. Medians were then determined and used to accomplish a "model" to identify a specimen. The sample sizes were not always a good representation of the morphology of a specific species, thus there were sometimes extreme measurements to either side of the values taken. Extreme values may be the result of external conditions and adaptations which may have caused exceptional growth or restraint thereof. Therefore it was decided to use the median instead of the mean, to avoid influence of extreme values until larger sample sizes are available.

The indices that were calculated in this study are stipulated in Table 3.9.

TABLE 3.9: Indices used in Stage 2

Index Abbreviation	Description
F(SCD) / F(GL) x100	Smallest circumference of femur / Greatest length of femur X100
T(SCD) / T(GL) x100	Smallest circumference of tibia / Greatest length of tibia X100
M(SCD) / M(GL) x100	Smallest circumference of metatarsal / Greatest length of metatarsal X100

2.3 Development of computer programme

The aim of the computer programme was to use the measurements of the modern specimens in a data base to manipulate the data in such a way that it might be able to identify a specimen as belonging to a certain species.

The development of the program was done during the study by the author and a computer programmer. Specifications of the programme were developed during the course of the study. The programme needed to illustrate a labeled identification percentage probability-graph when measurements are entered one by one. This ensures that a probability could be calculated with any number of measurements. This is especially important with the abundance of fragmented specimens from South African sites. The programme also has to be able to calculate various percentage probabilities. The identification percentage probability (IPP) is a calculation of the number of measurements (median values of specific species) that fall within the range of the entered measurement values, expressed as a percentage value. The range is a fluctuation of 10% either side of the median. The programme then calculates this percentage for all the species in the database. The fractional percentage probability (FPP) calculates the percentage chance the specimen measured has of being one of the species that had positive identification percentage probabilities (IPP). A species, for example, may have a 88% IPP but a 45% FPP depending on how many species met the requirements of the entered measurement values.

All measurements were entered into a D-Base database supported by Lotus Smartsuite. Lotus Smartsuite offers an integrated combination of utilities and it is relatively easy to use to build comparisons of structures and trends as well as profiles. Lotus Smartsuite incorporates a database but also yields a strong statistical and graphical interface. Separate fields were created to accommodate the entering of data.

The identification chart utilizes the measurements of the actual samples and collates it in a database to calculate the median or model thereof. By using linear regression analysis to set off actual sizes against these medians, the programme arrives at a possible identification of the specific species. The median was used to arrive at a specific species resembling the closest average without compromising the model with extreme values.

When the measurements of an unknown specimen are presented to the programme, the computer will compare the entered information to that contained within the database. An "IF" statement within the programme tests the actual measurement given to the model and allocates a "1" (true) or a "0" (false) in each measurement category. The sum total of the statements is then calculated and expressed as a percentage-of-compliance-to-the-model in terms of a hundred percent. It therefore gives an indication of which portion of the hundred percent the specific species presents and then provides the species "model" most accurately resembling those measurements. Only species with a total greater than zero is displayed graphically with the highest scoring species as the most likely identification.

Because of the limitation of data due to sample size constraints, a fuzzy-logic element or discernable flux was built into the programme. This allows for a 10% fluctuation off the median either way in returning species profiles. As more measurements are accumulated in the database, this fluctuation will decrease and a more refined model can be construed to increase accuracy. An accurate indication of not only the identification of the species, but also other species with similarities can be seen with the existing data.

The percentages of species possibilities are displayed graphically upon identification. The identification graph also stipulates which Bovid size class the identified species falls within. Thus if a number of possible species are identified on the graph and a definite result cannot be deduced from the percentage values, the bovid size class can be used, as in conventional methods, to classify the bone.

It is not necessary for all measurements to be entered into the separate measurements fields, but the number of measurements does have an influence on the accuracy of the identification. Thus obviously the more measurements entered the better the results.

The programme is divided into three separate databases for each long bone. It is therefore essential to already know from which long bone the specimen originated.

This is only a test programme, to ascertain whether bone measurements may yield accurate diagnoses of faunal remains. The database is also designed to protect sensitive or source information not intended for public scrutiny and change.

Future expansion of the database include adding additional information regarding each species. This information includes area of distribution, feeding type, habitat, average weight as well as a photographic illustration of the specific species. The area of distribution may differentiate between skeletally similar species, like Blesbok and Bontebok, on the basis of their natural occurrence. One species was used to demonstrate how additional information may be added in future to assist identification.

3. STAGE 3 - TESTING

Stage 3 comprised of a test of accuracy and reliability of the developed programme in Stage 2. Bones of Kemp's Caves, analyzed by conventional methods, were analyzed by the computerized classification system. This faunal sample included only one femur, three tibiae and six metatarsal specimens which could be utilized for testing. These specimens were the only material which were identified to species level belonging to the three lower limb long bones used in this study. Table 3.10 gives a summary of the specimens, their LKC number, the provenance and the identification based on the conventional method of faunal analysis.

Each fragmented specimen was measured using the measurements defined in Stage 2. These values were entered into the database to be identified by the computerized classification programme according to osteometric characteristics. No specimen was complete, thus all material lacked certain values.

TABLE 3.10: Kemp's Caves specimens used to test computerized classification

DESCRIPTION	LKC NO.	PROV.	SPECIES
Proximal articulation + shaft of right metatarsal	LKC/92/34	2E/8N	Blesbok
Proximal articulation + shaft of left metatarsal	LKC/93/35	5E/9,10N	Blesbok
Proximal articulation + shaft of left metatarsal	LKC/93/40	5E/9,10N	Blesbok
Proximal articulation + shaft of left metatarsal	LKC/94/328	5,6E/10N	Blesbok
Proximal articulation + shaft of left metatarsal	LKC/93/126	5E/9N	Impala
Left metatarsal	LKC/93/302	5,6E/9,10N	Reedbuck
Distal articulation + shaft of left tibia	LKC/93/70	5E/9,10N	Blesbok
Distal articulation of right tibia	LKC/93/23	5E/9N	Impala
Distal articulation + shaft of tibia	LKC/92/38	2E/6N	Springbok
Midshaft of left femur	LKC/94/27	6E/10N	Red Hartebeest

Ten modern museum specimens, which were not measured for the database for reasons of unavailabilty at the time, were also measured and the values were entered into the computer programme. The reason for the extra specimens was that these bones were of known animals, thus, identification was not based on conventional faunal identification methods which could be faulty. The second reason was to increase the number of specimens to better test the computer programme.

Table 3.11 gives a summary of the modern specimens and the allocated National Flagship Museum number. Each specimen was measured according to measurement descriptions in Stage 2. All the modern specimens were complete and all measurements were entered into the computer programme for identification.

TABLE 3.11: Modern specimens used to test computerized classification

DESCRIPTION	MUSEUM NUMBER	SPECIES
Femur	AZ 1069	Klipspringer
Femur	AZ 526	Grey Rhebuck
Femur	AZ 645	Red Hartebeest
Tibia	AZ 782	Steenbok
Tibia	AZ 1032	Springbok
Tibia	AZ 145	Black Wildebeest
Metatarsal	AZ 1572	Cape Grysbok
Metatarsal	AZ 931	Bontebok
Metatarsal	AZ 127	Sable
Metatarsal	AZ 1457	Eland