A comprehensive procedure to measure the body dimensions of large African predators with comments on the repeatability of measurements taken from an immobilized African lion (*Panthera leo*)

H. O. de Waal*, W. J. Combrinck and D. G. Borstlap

African Large Predator Research Unit (ALPRU), Department of Animal, Wildlife and Grassland Sciences (70), Faculty of Natural and Agricultural Sciences, University of the Free State, PO Box 339, Bloemfontein, South Africa

(Accepted 30 September 2003)

Abstract
Specific procedures are described to measure the body dimensions of large African predators; these include measurements of body and tail length, head, canines, mane, limbs, paws and testes. Data on body mass and dimensions were collected from an immobilized sub-adult male African lion *Panthera leo*. He was 40 months old and weighed 190 kg. After being immobilized, data on body mass and dimensions were collected by a team comprising a scribe, two operators and assistants. The procedures of measuring the 43 variables on body dimensions were then repeated three times in quick succession, each session lasting about 10 min. The four sessions were handled as if a different individual was measured each time. Except for reports on body mass of lions, there is a paucity of comparable data in the literature for most of the variables presented in this paper. The small dispersion measures of the 43 variables suggest that the specific procedures to measure the body dimensions of a large African predator such as the lion have a high degree of repeatability and can be applied with confidence. The procedure has been used to obtain data on body dimensions of a large number of lions as well as dead specimens of black-backed jackal *Canis mesomelas*, caracal *Caracal caracal* and Cape fox *Vulpes chama*. The data form part of a database on body dimensions of large African predators created by ALPRU. The objective is to develop non-invasive techniques to determine whether wild predator populations might have been subjected to abnormal growth and development as a result of negative impacts on their habitat and thus food base.

Key words: body measurements, large African predators, morphometric analysis, repeated measurements

INTRODUCTION
The body mass and dimensions of animals show large variation (Sachs, 1967; Smuts, Anderson & Austin, 1978; Smuts, Robinson & Whyte, 1980; Mills, 1982). Some body measurements can be taken with greater accuracy than others (Bertram, 1975; Skinner & Smithers, 1990), but differences in measuring techniques may contribute to the variation, which can be reduced by applying standard procedures when collecting data for morphometric analysis (Ansell, 1965; Sachs, 1967; Smithers, 1973; Mills, 1982).

Smuts *et al*. (1980) conducted a study with African lions *Panthera leo*, taking body measurements from 158 males and 186 females that were captured or killed in the Central District of the Kruger National Park, South Africa between 1974 and 1978. In their opening remark, the authors stated: ‘Despite many wild lions (*Panthera leo*) having been handled both dead and immobilized in the past, surprisingly little has been published on aspects of their growth or even the average weights or body dimensions of adult specimens.’ In this regard, Bertram (1975) described a procedure where a person could weigh even large male lions single-handedly, and commented: ‘Weighing large animals does not necessarily require huge tripods, trees, spring balances and teams of assistants.’ Technological advances and improved techniques may have assisted since in aiding the weighing and measuring of immobilized or dead animals, yet it appears that the situation as depicted by Smuts *et al*. (1980) has changed little since.

Measuring the body of an immobilized animal, particularly large African predators, is time consuming and, depending on the specific objectives, often has to compete with other activities such as collecting biological samples (e.g. blood) or fitting radio collars to animals. Furthermore, limited numbers of animals are available at irregular intervals for morphometric measurements and subjected by different operators to a range of measuring

*All correspondence to: H. O. de Waal.  
E-mail: deWaalHO.SCI@mail.uovs.ac.za
techniques. In this regard it should be noted what Smithers (1973) stated: ‘In our endeavours to contribute to our knowledge of our mammalian fauna there is an ethical responsibility on those of us who collect mammals to ensure that the best possible use is made of these by ensuring that as much data as possible is obtained from each and every specimen handled.’ According to Bertram (1975) body length of immobilized lions depended greatly on the posture of the animal; repeat measurements of the body length of the same animal were not consistent. It is safe to assume that solid or rigid objects such as skulls (Yamaguchi, 2002) can be measured with greater accuracy than what is possible with the procedures used to measure the flexible body of an animal in the flesh (either dead or immobilized). Nevertheless, the procedures suggested for measuring and some of the data published on several large African predators concentrated mostly on body mass (Smithers, 1973; Smuts, 1976, 1979; Bester, 1979; Smuts et al., 1980; Grobler, 1982; Mills, 1982; Anderson, Richardson & Woodall, 1992; Standers, 1992), body length or total length (Smithers, 1973; Bester, 1979; Grobler, 1982; Mills, 1982), tail length (Smithers, 1973; Bester, 1979; Grobler, 1982), hindfoot (Smithers, 1973; Bester, 1979; Grobler, 1982; Mills, 1982), ear length (Smithers, 1973; Bester, 1979; Grobler, 1982; Mills, 1982), heart girth (Smuts et al., 1980; Grobler, 1982; Mills, 1982), shoulder height (Bester, 1979; Smuts et al., 1980; Grobler, 1982; Mills, 1982), neck circumference (Mills, 1982) and vertebral column (Smuts et al., 1980). In a few cases very specific data were collected and published, notably on the dimensions of the skulls and teeth of lions (Smuts, Hanks & Whyte, 1982) and the digestive tract anatomy of the aardwolf Proteles cristatus (Anderson et al., 1992).

Among its activities, ALPRU has started a database on the body mass and dimensions of large African predators. The objective is to use the data in developing non-invasive techniques to determine whether wild predator populations might be subjected to abnormal growth and development, primarily as a result of factors impacting on their habitat and food base. Such non-invasive techniques will not require immobilization of large predators. To standardize and improve the activity of obtaining relevant data, a comprehensive procedure was developed to measure specimens and record morphometric data collected from dead or immobilized large African predators. In an adult male African lion with a well-developed mane extending down to his abdomen, this procedure comprises a list of 45 variables (de Waal et al., 2002) which has since been extended to include 47 variables. However, because every variable is measured only once which is the standard procedure for similar activities, this raised important questions regarding the repeatability of body measurements taken from large animals such as immobilized African lions. Strangely, it seems that the application of the so-called standard procedures for measuring animals for morphometric analysis (Ansell, 1965; Sachs, 1967; Smithers, 1973; Mills, 1982) assumed a high repeatability and inherent operator errors without question.

MATERIALS AND METHODS

The data were collected from a 40-month-old sub-adult male African lion (ALPRU00035) on a wildlife ranch. After being immobilized, data on 44 variables (namely for body mass and 43 variables on body dimensions) were collected by a team comprising a scribe, 2 operators and assistants. The same procedures for measuring the 43 variables were then repeated 3 times in quick succession, each session lasting about 10 min. The 4 sessions were handled as if a different lion was measured each time.

The lion was weighed only once with an electronic cattle scale to the nearest 0.5 kg. The remainder of the comprehensive list of 47 variables on body dimension of large African predators measured by ALPRU comprises the following.

A cloth measuring tape is used to measure:

- Body length: from the bases of the incisors (prosthion; most anterior point of skull), over the nose, following a line between the eyes over the head and along the contours of the body to the tip of the last vertebra of the tail. In the lion this was taken as the bony tip of tail, excluding the tail tuft.
- Tail length: from its proximal base to the tip of the last tail vertebra (same as above).
- Tail circumference: at its proximal base.
- Heart girth: circumference of the chest immediately behind the front limbs.
- Abdominal girth: circumference of the abdomen immediately before the hind limbs.

A large vernier calliper is used to measure:

- Head length: a straight line from the bases of the incisors (prosthion; most anterior point of skull) to the inion (most posterior point of the skull).
- Head width: a straight line between the zygions (most outer points of the zygomatic arches).

A small sliding vernier calliper is used to measure:

- Rostrum width: the outer width of the rostrum, just above the maxillary alveoli (width between the 2 upper or maxillary canines in a straight line between their labial bases at the gum).

And for each of the 4 canines:

- Canine length: length or height from the unbroken tip to its base on the gum.
- Canine, longer width: anteroposterior diameter at its base on the gum.
- Canine, shorter width: mediolateral diameter at its base on the gum.

A metal ruler is used to measure mane length or the extent of mane development at 8 defined sites:

- Top line: dorsal line, midway between head and shoulders.
Table 1. Mean and dispersion measures of five body measurements taken during four consecutive data collecting sessions from a sub-adult male African lion Panthera leo

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD (mm)</th>
<th>Range (mm)</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body length</td>
<td>2945.0 ± 33.2</td>
<td>80</td>
<td>1.1</td>
</tr>
<tr>
<td>Tail length</td>
<td>931.5 ± 16.1</td>
<td>38</td>
<td>1.7</td>
</tr>
<tr>
<td>Tail circumference</td>
<td>255.0 ± 6.6</td>
<td>14</td>
<td>2.6</td>
</tr>
<tr>
<td>Heart girth</td>
<td>1264.5 ± 21.4</td>
<td>46</td>
<td>1.7</td>
</tr>
<tr>
<td>Abdominal girth</td>
<td>1171.0 ± 68.5</td>
<td>164</td>
<td>5.8</td>
</tr>
</tbody>
</table>

* CV, coefficient of variance (see text).

- Between ears: at the inion (the most posterior point of the skull).
- Base of neck: ventral line of neck.
- Side of neck: lateral point of neck, midway between head and front limb.
- Breast bone: ventral spot on sternum between front legs.
- Belly: ventral spot on abdomen between anterior teats.
- Along top line: the distance from the inion (the most posterior point of the skull) to the furthest point where growth of the mane stops on the back of the lion.
- Covering of front limbs/shoulder: the distance from the shoulder joint (between the humerus and scapula) in a horizontal line in an anterior or posterior direction to where the mane stops.

A metal measuring tape is used to measure:

- Front legs, length: from the elbow to the tip of the longest digit, without claw (*sine unguis*).
- Front legs, circumference: thickest proximal part of the front leg (below elbow).
- Hind feet, length: from the heel to the tip of the longest digit, without claw (*sine unguis*).
- Paws, length: posterior part of sole pad to tip of longest digit, without claw (*sine unguis*).
- Paws, width: widest part across outer digits.

A small sliding vernier calliper is also used to measure the length and diameter of the testis.

The data were statistically analysed using GLM procedures of SAS (1991).

**RESULTS AND DISCUSSION**

The sub-adult male lion weighed 190 kg. It was not the objective to compare data on measurements of lions, but there is a paucity of comparable data in the literature for most of the variables presented in this paper, except for reports on body mass of lions (Smuts, 1976; Smuts et al., 1980; Stander, 1992). As a general observation, the dispersion measures of the 43 variables on body dimensions measured in this study are small (Tables 1–6). It is also worth mentioning that we measured 34 lions of both sexes and different sizes in quick succession during the previous day and part of that morning before this

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD (mm)</th>
<th>Range (mm)</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testis, left length</td>
<td>61.4 ± 3.5</td>
<td>7.5</td>
<td>5.8</td>
</tr>
<tr>
<td>Testis, left diameter</td>
<td>39.6 ± 2.9</td>
<td>6.5</td>
<td>7.2</td>
</tr>
<tr>
<td>Testis, right length</td>
<td>55.8 ± 2.6</td>
<td>6</td>
<td>4.7</td>
</tr>
<tr>
<td>Testis, right diameter</td>
<td>41.3 ± 2.2</td>
<td>5</td>
<td>5.4</td>
</tr>
</tbody>
</table>

* CV, coefficient of variance (see text).
sub-adult male lion (ALPRU00035) was measured. Therefore, we had already gained considerable practical experience in applying the specific measuring techniques over a short period of time. However, it is important to note that the standard procedures for taking measurements on mammal specimens (Smithers, 1973) ostensibly assume both a high repeatability and little or no operator errors.

One of the operators was tasked to collect the data presented in Tables 1, 3 and 4, as well as those in Table 2, but excluding the data on the rostrum width. The second operator collected the data on the rostrum width (Table 2) and the data presented in Tables 5 and 6. No obvious pattern of inconsistency or disparity was discernable in the data collected by the two operators. It should be noted that each of the 43 variables was not measured four times in succession, but all 43 variables were measured on the lion before the whole procedure was repeated from scratch for a second, a third and a fourth time as if four different lions were measured.

The body length of wild cats is commonly used as a variable in describing their size (Green, 1991). The body length of the sub-adult male lion was 2945.0 ± 33.2 mm (Table 1) and varied 80 mm between the four successive sessions. The CV (coefficient of variation = (standard deviation/mean) * 100]) of 1.1% for repeated measurements of body length is very small. The ALPRU procedure used in this study to measure body length differs slightly from that described by Skinner & Smithers (1990) as the total length of a specimen measured ‘between the pegs’, where the tip of the nose is designated the anterior point of a specimen. The tail length was 931.5 ± 16.1 mm (Table 1) and although it contributed only 32% to body length, the range of 38 mm for the four measurements of tail length comprised about half of the range for body length (80 mm). Considering the rigid nature of the skull and vertebrae, little variation was expected for these body dimensions. However, during the process of measuring the immobilized lion, its head, neck, body, limbs and tail were moved about and extended to facilitate measuring the different parts. Therefore, slight distortions in the relative positions of some vertebrae along the length of the vertebral column between the four successive measuring sessions may account for some of the variation in body length; more so in the tail. Variation in repeated measurements of tail circumference was small (Table 1).

It is envisaged that this variable may assist in determining body condition.

Lions gorge themselves with large quantities of prey carcass in a single meal (Schaller, 1972; Bertram, 1975). The actual mass (Smuts, 1979) or estimated mass (Bertram, 1975) of stomach contents are usually subtracted from the body mass of lions to give more realistic values of body mass (Bertram, 1975; Smuts et al., 1980), but often body mass of lions is not corrected for stomach content (Smuts, 1976). However, this practice to correct body mass for the remains of the last meal that might still be contained in the stomach or digestive tract may be misleading and can introduce substantial error. For example, Smuts et al. (1980) reported on a 5-year-old male lion that was in excellent physical condition and weighed 225 kg. Externally the lion would have been classed as having an above average stomach fill. However, a postmortem showed that it had an empty stomach but contained large amounts of subcutaneous and intestinal fat. In the current study both the heart girth and the abdominal girth were measured. The range of repeated heart girth measurements was only 46 mm (Table 1). In comparison the range of 164 mm for repeated measurements of abdominal girth was the largest of all 43 variables analysed. The sub-adult lion had eaten more than 84 hours prior to being measured, therefore, stomach fill could not have contributed much to the variation. However, the relatively large variation in abdominal girth between successive measurements could more likely have been ascribed to physical activities, creating movement of the intestines during the process of measuring the immobilized lion. As discussed previously, during this procedure its head, neck, body, limbs and tail were moved about and extended to facilitate measuring the different parts, which may have caused physical movement and even temporary lumping of the intestine in the lower abdomen, causing changes in abdominal girth.

In describing the size of African lions references are often made to shoulder height (Smuts et al., 1980; Green, 1991). Similarly, references to and data for shoulder height are provided for other animals (Sachs, 1967; Mills, 1982; Skinner & Smithers, 1990). However, Smuts et al. (1980) specifically pointed out that the measurement of shoulder height was not the same as the standing height of a lion. In this regard, Bertram (1975) also concluded that limb measurements of lions proved unsatisfactory since they were very unreliable except with completely relaxed animals; even then they were somewhat inaccurate and arbitrary. At the very first attempt at measuring this variable in an immobilized adult lioness, it seemed futile to attempt measuring this variable when an animal is lying

### Table 6. Mean and dispersion measures of 12 measurements of the upper and lower canines taken during four consecutive data collecting sessions from a sub-adult male African lion Panthera leo

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD (mm)</th>
<th>Range (mm)</th>
<th>CV(^a) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canine, left upper, length(^b)</td>
<td>50.1 ± 0.3</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Canine, left upper, longer width(^c)</td>
<td>24.1 ± 0.6</td>
<td>1.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Canine, left upper, shorter width(^d)</td>
<td>18.8 ± 1.7</td>
<td>4</td>
<td>9.1</td>
</tr>
<tr>
<td>Canine, right upper, length</td>
<td>51.9 ± 0.6</td>
<td>1.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Canine, right upper, longer width</td>
<td>25.0 ± 0.8</td>
<td>2</td>
<td>3.3</td>
</tr>
<tr>
<td>Canine, right upper, shorter width</td>
<td>18.8 ± 1.3</td>
<td>3</td>
<td>6.7</td>
</tr>
<tr>
<td>Canine, left lower, length</td>
<td>41.0 ± 0.8</td>
<td>2</td>
<td>2.0</td>
</tr>
<tr>
<td>Canine, left lower, longer width</td>
<td>22.8 ± 1.3</td>
<td>3</td>
<td>5.5</td>
</tr>
<tr>
<td>Canine, left lower, shorter width</td>
<td>16.6 ± 0.5</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>Canine, right lower, length</td>
<td>40.3 ± 1.5</td>
<td>3</td>
<td>3.7</td>
</tr>
<tr>
<td>Canine, right lower, longer width</td>
<td>21.5 ± 1.3</td>
<td>3</td>
<td>6.0</td>
</tr>
<tr>
<td>Canine, right lower, shorter width</td>
<td>16.3 ± 1.3</td>
<td>3</td>
<td>7.7</td>
</tr>
</tbody>
</table>

\(^a\) CV, coefficient of variance (see text).
\(^b\) Length or height from the unbroken tip to of canine to its base on the gum.
\(^c\) The anteroposterior diameter of a canine at its base on the gum.
\(^d\) The mediolateral diameter of a canine at its base on the gum.
down. The distortion of the front limbs including the paws when a lion is standing upright in a normal relaxed posture, relative to the extended positions when lying prostrate, makes meaningful extrapolation questionable. Therefore, measuring the shoulder height (Bester, 1979; Smuts et al., 1980; Grobler, 1982; Skinner & Smithers, 1990) of large African predators when lying down has been omitted from the list of variables proposed by ALPRU and considered in this study.

The length of the skull has been defined by Smuts et al. (1978) as the greatest length from the front of the premaxilla to the lambdoid crest and the width of the skull as the greatest width measured across the zygomatic arches. The measurements can be taken with a large vernier calliper or with a specially prepared measuring board in a straight line or so-called between pegs as described by Smuts et al. (1978). The skull is the most rigid object among the variables measured in the lion; therefore, it was expected that the variation between successive measurements in the length and width of the head of the lion in this study would be small.

Given the relative size of these two dimensions, the variation was indeed small (Table 2); especially because the measurements of the skull in live lions may be affected by gum, muscle, skin and hair covering the skull. It is worthy to note that the trophy size of lions is taken as the sum of the measurements of the length and width of a lion skull (Anonymous, 1993). The variation in rostrum width (Table 2) of the maxillary canines for repeated measurements is also small.

Sexual dimorphism in African lions, specifically the heavy manes of most adult male lions, is a pronounced and well-known characteristic (Smuts et al., 1980). Apart from the general qualitative descriptions and references to the manes of African lions, no quantitative data on mane length is available in the literature. To date, the length of the manes of 18 sub-adult and adult male African lions have been measured according to this procedure, including this sub-adult male (ALPRU00035). The sub-adult male had no mane on its belly and it can be assumed that his mane had not reached its full length yet (Table 3). No data are presented for positions seven and eight of the manes, since these two variables have been added to the procedure more recently to improve the quality of the data. The data on the length of the mane of the sub-adult male suggest that the variation associated with measuring the mane was generally larger than for most of the other variables. This may relate to the measuring procedure of having to judge rather arbitrarily the mean length of a tuft of mane hairs, comprising several individual hairs of varying length held closely next to a metal ruler. The mean length was not determined by actually measuring the length of a number of single strands of hair from the mane.

The unreliability of shoulder height measurements does not apply to specific sections of the limbs, especially the parts below the elbow and heel. In our study the variation between repeated measurements of both front legs and hind feet was reasonably small (Table 4). An exception was the range of 43 mm between repeated measurements for the length of the left front leg. The larger dimensions of the front paws of the lion compared to the hind paws, both for length and width, are clearly shown in Table 4. Spoor of lion has been used to identify or determine the sex of animals (Stander et al., 1996; Schultz & Turk, 2002). It should be noted that the dimensions of the paws provided in Table 4 would be smaller than the actual spoor of the lion (Stander et al., 1996; Schultz & Turk, 2002) because the sole and digit pads would expand under its full weight when walking or standing. The type of substrate, namely clay, sand or firm soil, also plays an important role in shaping the spoor.

The variation in the dimensions between repeated measurements for the length and diameter of testes was to be expected (Table 5). The testes are soft organs and the operator applied extreme caution during the measuring process not to injure or damage the testes, which may have compromised accuracy.

Apart from the impressive manes of most adult males, lasting impressions of African lions and lionesses are the wide gaping mouths with long canines and arrays of incisors. Sexual dimorphism in the maxillary and mandibular permanent canines of lions is sufficient to allow the sex to be assigned to a specific canine and therefore a skull of unknown origin (Smuts et al., 1978). Bearing in mind that it is very difficult to open the jaws and measure the canines of a lion, even when it is immobilized, the dimensions of the canines presented in Table 6 show relatively little variation between repeat measurements. The dimensions of the canines (Table 6) also show that the maxillary canines are about 10 mm longer than the mandibular canines.

CONCLUSIONS

It might be argued that the sample size of four repeated measurements, for each of the 43 variables on body dimensions, on the sub-adult male African lion was too small. However, the small dispersion measures of the 43 variables measured in this study suggest that the procedures to measure the body dimensions of large African predators such as lions have a high degree of repeatability and can be applied with confidence.

The procedure has since also been used with great ease and confidence to obtain data on the body dimensions of dead specimens of the black-backed jackal Canis mesomelas, caracal Caracal caracal and Cape fox Vulpes chama. The data form part of a database on body dimensions of large African predators created by ALPRU. The objective is to develop non-invasive techniques to determine whether wild predator populations might have been subjected to abnormal growth and development as a result of negative impacts on their habitat and thus food base.

Acknowledgements

The authors are indebted to Mr Thys Mostert who made it possible to conduct this trial and to Mr Mike Fair for skillfully guiding the data through the statistical
procedures. Members of the ALPRU team, especially Elizma Theron, Melanie Pieterse and Daryl Barnes are thanked for their assistance in collecting the data.

REFERENCES


